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HOUSE OF COMMONS SESSION 1995–96

SCIENCE AND TECHNOLOGY COMMITTEE

Fourth Report

THE PARTICLE PHYSICS AND ASTRONOMY RESEARCH COUNCIL

Report together with the
Proceedings of the Committee

Ordered by The House of Commons *to be printed*
11th July 1996

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The Science and Technology Committee is appointed under Standing Order No 130 to examine the expenditure, administration and policy of the Office of Science and Technology and associated public bodies.

The Committee consists of 11 Members. It has a quorum of three.

The Committee has power:

(a) to send for persons, papers and records, to sit notwithstanding any adjournment of the House, to adjourn from place to place, and to report from time to time;

(b) to appoint specialist advisers either to supply information which is not readily available or to elucidate matters of complexity within the Committee's order of reference;

(c) to communicate to any other such committee and to the Committee of Public Accounts and to the Deregulation Committee its evidence and any other documents relating to matters of common interest; and

(d) to meet concurrently with any other such committee for the purposes of deliberating, taking evidence, or considering draft reports.

Unless the House otherwise orders, all Members nominated to the Committee continue to be members of it for the remainder of the Parliament.

The following were nominated Members of the Committee on 13 July 1992:

Mr Spencer Batiste
Dr Jeremy Bray
Mr Malcolm Bruce
Mrs Anne Campbell
Cheryl Gillan
Mr William Powell
Sir Giles Shaw
Sir Trevor Skeet
Dr Gavin Strang
Sir Gerard Vaughan
Dr Alan W Williams

Sir Giles Shaw was elected Chairman on 15 July 1992.

On 9 November 1992 Mr Malcolm Bruce was discharged and Mr Andrew Miller added to the Committee

On 16 November 1992 Dr Gavin Strang was discharged and Dr Lynne Jones added to the Committee.

On 7th November 1995 Cheryl Gillan and Mr William Powell were discharged and Mr Ian Bruce and Mr Patrick Thompson were added to the Committee.

The cost of preparing for publication the Shorthand Minutes published with this Report was £2,226.99.
The cost of printing and publishing this Volume is estimated by HMSO at £5,020.

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FOURTH REPORT

THE PARTICLE PHYSICS AND ASTRONOMY RESEARCH COUNCIL

The Science and Technology Committee has agreed to the following Report:

I. INTRODUCTION

1. The Particle Physics and Astronomy Research Council is part of the new Research Council structure announced in *Realising our Potential* in 1993.[1] The new Research Council Charters came into force on 1st April 1994. We have refrained from conducting any inquiry into the Research Councils until now to allow time for the system to become established, and for the new Research Councils to define their priorities and working methods. We consider it is now appropriate to examine the new system and the Councils within it and we expect this to be the first of a series of Reports.

2. Our previous inquiries have been concerned with science policy, and with areas in which the chief concerns were about the applications of research.[2] We were, accordingly, inclined to consider basic research in this inquiry. There were also pressing reasons for inquiring into the Particle Physics and Astronomy Research Council (PPARC).

3. When the White Paper was published there were fears that the emphasis on the role that research could play in increasing national prosperity could lead to a diminution in support for basic science; the establishment of the Particle Physics and Astronomy Research Council went some way to allay those fears. Unlike other Research Councils, PPARC's main aim, as set out in *Realising our Potential*, is explicitly "the improved understanding of the concepts and principles underlying physical phenomena and their consequences." The requirement to place "special emphasis on meeting the needs of users of its research and training output, thereby enhancing the United Kingdom's industrial competitiveness and quality of life," laid on the other Research Councils, is replaced by the injunction to "take account of the potential for contributing to the United Kingdom's industrial competitiveness and quality of life."[3]

4. Yet in spite of this recognition of the importance of basic science, almost from the time that PPARC was founded there were signs that its budget was extremely stretched. One of the first actions of Professor Pounds as PPARC Chief Executive was to tell the European Space Agency (ESA) that the United Kingdom could not participate in the INTEGRAL[4] project, although United Kingdom scientists had taken a lead in its design. PPARC's first Annual Report and Corporate Plan were unusually explicit in their claims that the Research Council lacked the money to fund its programmes properly.[5] This is not a time of financial stringency for PPARC alone. "Big science" projects are being reconsidered in other countries. An American project to build an advanced particle accelerator, the "Superconducting Super Collider" (SSC), was cancelled in 1993 on the grounds of its cost.[6]

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[1] Cm 2250.

[2] See, for example, *The Routes through which the Science Base is Translated into Innovative and Competitive Technology*, HC(1993-94)74-I and *Human Genetics: The Science and its Consequences* HC(1994-95)41-I.

[3] Cm 2250, pp29-31.

[4] The International Gamma Ray Laboratory (INTEGRAL) is for accurate imaging of celestial gamma-ray sources, due for launch in 2001.

[5] *The First Corporate Plan of the PPARC*, 1995, p4 and *Business Plan 1995*, PPARC, pp3-6.

[6] *The Nature of Matter: International Collaboration in Particle Physics*, POST, June 1994, p28.

5. In spite of this financial stringency, in 1994 the United Kingdom was party to an agreement to build a new accelerator at CERN, the European Laboratory for Particle Physics. This machine, the Large Hadron Collider (LHC), will be the most sophisticated in the world and its construction cost has been estimated at 2,500 million Swiss francs.[7] The final decisions about the timetable for the construction of the LHC, and the experiments which are to be conducted on it, are to be taken in 1997. These decisions are likely to have a significant impact on PPARC's need for resources. It accordingly seemed particularly timely to open this series of inquiries with an examination of PPARC.

6. In the course of this inquiry we have received over eighty five submissions. We have also been able to draw upon the work of the Parliamentary Office of Science and Technology.[8] We have held three sessions of oral evidence. In the first we took evidence from Professor Culhane of the Mullard Laboratory, Professor George Kalmus, of the Rutherford Appleton Laboratory, and Sir Martin Rees, the Astronomer Royal. In the second session we heard from witnesses not immediately involved in or funded by PPARC. These were: Sir John Kendrew, Sir William Mitchell, Professor Mike Gunn and Professor Simon Donaldson. In the last session we took evidence from Dr Peter Williams, Chairman, and Professor Ken Pounds, Chief Executive, of PPARC. We visited CERN and ESA, where we held very helpful discussions with Professor Llewellyn Smith, the Director General of CERN, M Jean-Marie Luton, the Director General of ESA and Dr Roger Bonnet, the Director of the ESA science programme, and their colleagues. We also visited Oxford University, the Central Laboratory for the Research Councils, Manchester University and Jodrell Bank and Leicester University. We are very grateful to those who hosted these visits and all those who gave us evidence, both written and oral. We have been assisted by our Specialist Advisers, Professor Malcolm Longair and Professor Sir Peter Swinnerton-Dyer; we very much appreciate their help.

II. PPARC FUNDED RESEARCH

7. PPARC funds research into space science[9], particle physics and ground based astronomy. There is some similarity between these disciplines, in that they all require expensive equipment, often provided through international collaboration, and they examine the fundamental properties of the universe, from sub-atomic particles to galactic systems. The demarcation between the subjects is significant but it is not absolute - for example some research into the as yet undetected "dark matter", which may account for ninety per cent of the mass of the universe, spans astronomy and particle physics; and research into the early universe can span both disciplines. In general, however, researchers into particle physics and astronomy (and even into space science and ground based astronomy) form distinct communities with quite different ways of working.

PARTICLE PHYSICS

8. High energy particle physics looks at the deep structure of the atom. It gains its results by smashing subatomic particles together and looking at the "debris" of their collisions. The particle physics programme depends on having the facilities necessary to accelerate particles to the tremendous speeds required to do this. The accelerators operate simply to bring particles to the speeds required; experiments are then needed to capture and analyse the products of collisions between the particles. (In particle physics the term "experiment" is

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[7] *The Next Step*, CERN 1993, p37.

[8] *The Nature of Matter: International Collaboration in Particle Physics*, POST, June 1994, *Looking Down on Earth: the Future of Earth Observation from Space*, POST, January 1996, and briefing note on PPARC prepared for the Committee (deposited in Library).

[9] In this context, space science means astronomy conducted from space, planetary and solar system science and the study of the interplanetary medium. Earth observation is now the responsibility of NERC.

reserved for the configurations of detectors which fit round the pipe of the accelerator at the points where collisions occur). Each experiment is constructed of layers of different kinds of detectors which rely on advanced engineering and computing technology to distinguish the millions of interactions occurring each second, and to identify and capture those worth recording. Once an "experiment" is installed it can be expected to run for up to a decade, although it may be extensively modified over that time. Dr M A Parker, a member of the LHC planning group, stated

> "It is a common misconception that large experiments address only a few issues. In fact, each new accelerator gives access to a wide new field of physics, at higher energies and smaller distances. ... Each group in the experiment is then able to investigate particular issues suited to its expertise and interest."[10]

9. The range of technology required and the timescales involved mean that particle physicists work in extremely large groups. The LEP collider currently in use at CERN has four experiments running upon it - ALEPH, DELPHI, OPAL and LEP3. Each uses a different combination of detector techniques. Hundreds of scientists are involved in each experiment; at least one of the experiments projected for the LHC will involve fifteen hundred scientists.[11] The particle physics community contains experts in many disciplines such as high performance computing, superconductivity and electronics as well as theoretical particle physicists who may also suggest modifications to the experiments which would provide the data they need.

10. There are no longer any facilities for experimental high energy particle physics in the United Kingdom. In the mid 1970s the United Kingdom decided to close down its domestic accelerator programme and concentrate its efforts in CERN and other international collaborations.[12] Most of these experiments take place at the complex of accelerators in CERN but particle physicists from the United Kingdom are also involved in the German National Laboratory (DESY) on the electron-proton collider HERA. Some British physicists are also active at the Stanford Linear Accelerator in the USA.

11. The work on particle accelerators is complemented by a range of other experiments, which receive lower levels of funding. For example, one hypothesis suggests that the "dark matter"[13] is made of particles which interact very weakly indeed with ordinary matter. Millions of these particles, known as weakly interacting massive particles (WIMPS), might pass through each square metre of the earth every second and they would be essentially unimpeded. Very occasionally, however, one of these hypothetical particles would interact with the nucleus of an atom, knocking it out of place. Detectors designed to look for signs of such collisions are being installed in deep mines in Yorkshire and in Italy.

12. CERN, the European Laboratory for High Energy Physics, was founded after the second world war.[14] It has been a key factor in ensuring European success in particle physics, designing and building an ever more sophisticated range of accelerators and it now houses the largest number of accelerators gathered together in the world. Member states pay for the accelerators and the running costs of CERN through their subscriptions; groups of physicists then put forward proposals for experiments - basically configurations of detectors - and a choice is made on scientific grounds. The successful group pays about 75% of the detector

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[10] Ev p99.

[11] Ev p111.

[12] *High Energy Particle Physics in the United Kingdom*, ABRC 1985 (Kendrew Report), para E3, p29.

[13] Which may account for 90% of matter in the universe.

[14] The current Member States of CERN are: Austria, Belgium, Czech Republic, Denmark, France, Finland, Hungary, Germany, Greece, Italy, Netherlands, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland and the UK.

costs which have to be found in addition to the CERN subscription by the national agencies. Within these groups, smaller groups will be responsible for particular types of detector - for example, a group from Manchester University designed and manufactured the muon chambers for the OPAL experiment on the LEP accelerator at CERN. CERN's 1996 budget is 937.6m Swiss Francs;[15] the United Kingdom's subscription for 1996 is 131.3m Swiss Francs. The Sterling subscription for 1995-96 is £66.5m.[16]

13. The scale of the operation leads particle physicists to take a long view in considering future facilities. Last year the CERN council approved plans to build the Large Hadron Collider (LHC).[17] It is a good example of the long term foresight of the particle physics community that the LEP tunnel at CERN, which was under consideration in 1978, was designed to fit a future accelerator within it, should Council ever approve the project.[18] There are currently no firm ideas about a successor to the LHC, which will not be completed until 2005 even on the most optimistic estimates and should produce results for a decade or so once completed.[19]

ASTRONOMY AND SPACE SCIENCE

14. The astronomy programme encompasses a wider range of activities than particle physics, and these activities are conducted in many different ways. International collaborations can range from formal membership of treaty based organisations such as the European Space Agency (ESA),[20] to ad hoc arrangements set up by the scientists directly concerned. However this should not obscure the fact that, as Sir Francis Graham Smith, pointed out, "all research in our fields is very largely international".[21]

Ground Based Astronomy

15. Ground based astronomy can take many forms as astronomers use as much of the spectrum as they can through optical, infra-red and radio telescopes. The principal facilities operated by PPARC are

—the Anglo Australian Observatory in New South Wales, which contains optical and infra-red telescopes and is funded by PPARC and the Australian Research Council;

—the Isaac Newton Group of optical telescopes on La Palma, funded in collaboration with the Netherlands and the Republic of Ireland;

—the Joint Astronomy Centre on Mauna Kea, Hawaii which contains the UK Infra-red Telescope and the James Clerk Maxwell millimetre telescope which is operated in association with Canada and the Netherlands;[22]

—the UK is a also partner in the Gemini project which involves the construction of two 8-metre optical-infrared telescopes, one of which will be located on Mauna Kea in Hawaii and the other at Cerro Pachon in Chile. These telescopes are being constructed in collaboration with the USA, Canada, Chile, Brazil and Argentina. First light for the Gemini North telescope will be in 1998 and for Gemini South in 2000.[23]

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[15] *Budget of the Organisation for the Forty-second Financial Year 1996,* CERN.

[16] *Ibid.* The 1996 PPARC Business Plan gives the figure for the CERN subscription in 1995-96 as £69.5m; it indicates that £3m was paid for the following year, giving a total subscription for 1995-96 as £66.5m.

[17] A "hadron" is a subatomic particle which is itself composed of further particles - eg a proton which is made up of quarks. A "lepton" is a particle which cannot be further subdivided - eg an electron.

[18] CERN, *The Next Step,* November 1993, p7.

[19] Annex II, pliv.

[20] The current Member States of ESA are: Austria, Belgium, Denmark, France, Finland, Germany, Ireland, Italy, Netherlands, Spain, Sweden, Switzerland and the UK. Co-operation agreements have also been signed to allow Canada to participate in certain programmes.

[21] Ev p118.

[22] *The First Corporate Plan of the PPARC,* 1995, pp18-20.

While they require commitment of some continued expenditure to international facilities, and in some cases bind the United Kingdom by treaty, the scale of that commitment is small by comparison with that of CERN (£66.5m) and ESA (£38.5m) - the most costly, the inter-agency agreements for La Palma and Mauna Kea, cost some £11.5m.[24] Now that the island observatories are well established and have entered their long-term operational phase, it is more efficient to operate them as free-standing observatories rather than as outstations of the United Kingdom Observatories.[25]

16. The major national observational facility in the UK is the MERLIN array of radio telescopes which is managed by Manchester University at Jodrell Bank. In effect, by synchronising the observations made, the telescopes can distinguish the fine detail in sources as if they were a single telescope with a bowl as large as the distance between the farthest points; the effective aperture is over 230km.[26] The telescope is not confined to the United Kingdom; about four times a year the MERLIN network links with international networks in Europe and elsewhere in the northern hemisphere through a technique known as "Very Long Baseline Interferometry". These links are managed informally by participating radio observatories.[27]

17. Advanced instrumentation, which is developed both by the Royal Observatories and individual university groups, is crucial to the exploitation of ground based telescopes. The observatories also performed an important function in ensuring that expertise within the universities was accessible to possible collaborators from overseas. The skills needed to develop instrumentation are, like those needed in particle physics, many and varied; they include mechanical, optical, thermal, cryogenic, computer and systems engineering at the highest level. The recent prior options review of the Observatories recommended that their functions should be put out to tender.[28] Professor Pounds said "...I believe that it is very important that we do not lose some of this expertise in the competitive process, that is now going to develop."[29] **We hope that competitive tendering for services formerly provided by the Royal Observatories will lead to significant savings; it is essential that it should not lead to less skilled development and operation of the advanced instrumentation needed to maintain the telescopes at the forefront of astronomy and astrophysics.**

18. Observing time at any of the ground based facilities is awarded by peer review and is open to the entire community. While particle physics research tends to be done in very large collaborations, in astronomy small groups from a great number of universities have time awarded to them and may pursue independent lines of research.[30]

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[23] *Business Plan 1995*, PPARC.

[24] Ev p178.

[25] *Prior Options Review of the Royal Observatories: Report of the Steering Committee*, paras 4.1-4.3, 6.3.

[26] *Exploring the Universe with Merlin*, University of Manchester, Nuffield Radio Astronomy Laboratories Jodrell Bank, p8.

[27] Ev p118.

[28] *Report of the Steering Committee*, paras 10.1-11.2; *Business Plan 1995*, PPARC.

[29] Q253.

[30] Q84, Ev p24.

Space Science

19. Space based research is extremely diverse; broadly speaking, it can be divided into solar system science, concerned with our own system, and astrophysics, which provides information which is complementary to that provided by the ground based telescopes. The United Kingdom's activities in space science depend entirely on international collaboration,[31] chiefly through the European Space Agency. PPARC also has a number of bilateral collaborations in space, such as that on the Japanese solar mission, Yohkoh, and ROSAT, which operates in the X-ray and extreme ultraviolet part of the spectrum and which is a joint venture between the UK, Germany and NASA.

20. PPARC also provides funding for the CUTLASS and EISCAT ground based radar systems which study the uppermost layers of the atmosphere. These, too, are international projects. They can be used independently or in conjunction with satellites; for example, they can be used with the SOHO satellite's observations of changes in the sun's "weather" to investigate the effects of these changes on the earth.

21. The European Space Agency remains, however, the forum in which most United Kingdom space activities take place. ESA's programme is divided between the mandatory programme, which broadly speaking covers space science and general support costs, and the optional programmes, such as the development of launchers. The subscription for the mandatory programme is in relation to Net National Income; the level of participation in optional programmes is at the member's discretion.[32]

22. British activities in space are co-ordinated through the British National Space Centre (BNSC) which:

> "acts as a focus for the civil space interests of government departments. Its partners are the Department of Trade and Industry (DTI), including the Office of Science and Technology (OST), Ministry of Defence (MoD), the Meteorological Office, Foreign and Commonwealth Office (FCO), the Department of the Environment (DoE), the Natural Environment Research Council (NERC) and the Particle Physics and Astronomy Research Council (PPARC). Responsibility for funding space programmes remains with these individual organisations according to their responsibilities. BNSC provides overall coherence, facilitates links between the programmes and supports the Minister for Science and Technology at the DTI in his capacity as Minister for Space. The Defence Research Agency (DRA) and the Central Laboratory of the Research Councils (CLRC) are both directly linked to BNSC and carry out their space activities in close association with it."[33]

The BNSC also keeps in close contact with industry and academia, and its advisory panels contain representatives from these sectors.[34] ESA clearly has a strategic significance for the United Kingdom far beyond its role in space science; for example, the United Kingdom is also involved in optional ESA programmes on Earth Observation, telecommunications, and, recently, the further development of the Ariane 5 launcher. The DTI (c 50%) and PPARC (c 25%) are the largest contributors to civil space;[35] the total UK contribution to ESA in 1995-96 was £124.1m of which PPARC contributed £38.5m.[36] After the CERN subscription, this is the second largest item in PPARC's budget.

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[31] Ev p43.

[32] *UK Space Policy - a draft Forward Plan,* BNSC, June 1996, p33.

[33] *Ibid,* p9.

[34] *Ibid,* p10.

[35] *Ibid,* p32.

[36] *Ibid,* p34.

23. The arrangements for ESA scientific collaborations are in some ways similar to those in CERN. The science directorate, after long discussion among scientists from all member countries, will propose a programme to Council; this will deal with the satellites involved and the type of information to be gathered. Then groups of scientists will propose items of equipment to be carried on the mission. A successful group will then be expected to design and build the equipment it proposes, since the subscription to ESA covers only overheads and the building and launch of the satellite and basic telescope itself. The groups building the scientific instruments are much less likely to contain scientists from several countries than they are in particle physics, but several groups from various countries will work on any one mission.

24. The ESA programme is also defined far into the future. In 1985 ESA approved Horizon 2000, a long term research programme in space, designed to give Europe a key role in a number of areas of research. It is based on four cornerstone missions: SOHO-Cluster, the SOHO component of which was launched in December 1995; X-ray Multi-Mirror mission (XMM) planned for launch in mid 1999; Rosetta planned to be launched in 2003; and Far InfraRed and submillimetric Space Telescope (FIRST) planned to be launched in 2005. Smaller "medium" missions are approved in the course of the main Horizon programmes. ESA has now approved the Horizon 2000+ strategy, including new cornerstone missions to Mercury and Mars. This will take the programme up to 2010 and beyond.[37]

25. The first part of the first cornerstone mission, SOHO, was successfully launched in December 1995 and is designed to gather valuable information about the sun on its own. It was also intended that its results would complement the other part of the cornerstone mission, Cluster, which was to consist of four satellites flying in formation through the magnetosphere. Cluster was intended "to better understand the sun's weather and its effects on earth,"[38] and its effects on Earth and to provide the first real-time three-dimensional pictures of the changing interplanetary medium. The sun's "weather" can have significant effects on the earth's magnetic field; in the longer term, the magnetic activity of the sun may well affect terrestrial weather. In the short term solar activity can cause magnetic storms which have on occasion been severe enough to interfere with electrical transmissions over hundreds of miles. It will be vital to understand and predict such storms in a world increasingly dependent on electrical systems, such as computer operated systems. Not only would Cluster have been of great scientific interest; it might also have provided knowledge which would allow such problems to be avoided in future.

26. In June this year the space science programme suffered a severe set back, when the Ariane 5 launcher which was carrying the four Cluster satellites exploded. The four satellites had accepted a free launch on the first Ariane 5 test flight both because of the considerable cost savings involved and because the Cluster satellites were near the limit of the Ariane 4 payload. The satellites were not insured, since, as Professor Pounds told us:

> "it has never been the policy to insure science projects within ESA, a policy that - until two weeks ago - was justified by 14 consecutive successes since 1968 ... Given the extra uncertainty of the Cluster launch being on an untested rocket, I would guess the insurance premium for Cluster would have been *at least* 25%, or £60 million."[39]

27. We do not know how serious a setback this will be for the prospects of Ariane 5 as a commercial launcher. For space science it is certainly serious. The loss of Cluster is a tragedy which will affect the plans of many solar system scientists, with consequent damage

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[37] *Ibid,* pp16-17.

[38] Letter to Sir Giles Shaw from Professor Pounds (not printed; deposited in the Record office).

[39] See Annex IV, plix.

to their research careers. ESA is currently evaluating how to respond to this tragedy by developing a mission to carry out at least a significant part of the Cluster programme.

28. The Cluster satellites were the responsibility of ESA; the instruments aboard them were provided from the domestic science budget. **The scientific goals of the Cluster satellites were important and the scientific information they were to have gathered should not be lost for lack of funds.** Decisions about the replacement mission will have to be made within ESA. At its meeting on 2 July the ESA Science Programme Committee agreed:

> "(1) ESA will study the possibilities for carrying out a full Cluster replacement mission and the impact this may have on the ESA Horizons 2000 programme.
>
> (2) National Agencies, in case a full replacement mission proves not to be affordable, will work with ESA to investigate whether an alternative, lower-cost, option, possibly involving small satellites more commonly used in national programmes, can still be sufficient to achieve many of the prime mission objectives.
>
> (3) In parallel with the above, the spare spacecraft of the Cluster mission will be prepared for launch. It is recognised that none of the prime mission objectives would be achieved by launch of the spare spacecraft alone, but the Committee felt that there was a sufficiently strong science case for the launch, if there were no acceptable option for multi-spacecraft mission and taking into account that a single spacecraft mission would exploit existing investment at relatively modest incremental cost.
>
> At the November meeting of the Science Programme Committee a decision will be made on whether 1 or 2 is affordable. If neither option is viable, a decision will be made whether to proceed with the launch of the spacecraft. This would depend on the availability of a reliable launcher at a low cost to the ESA Science programme."[40]

If a new mission is recommended, individual countries will still have to find the resources for the instrumentation required. It is not Government policy to insure its assets;[41] it is extremely unlikely that Cluster would have been insured even if it had been the sole responsibility of the United Kingdom. *Government Accounting* states the "Treasury would not in normal circumstances expect to have to entertain bids for additional resources."[42] However, although as *Government Accounting* says, "the total size and range of the Government's business is so large" that it does not need to insure, individual parts of Government are more constrained. PPARC itself can only provide resources to replace the lost instrumentation if other projects are abandoned and the Science Budget as a whole is already under pressure and is projected to decline in real terms over the next three years.[43] **We recommend that the cost of any United Kingdom instrumentation on a mission to replace Cluster, up to the value of the instrumentation lost on the original project, should be borne by the Contingency Fund.** There is concern, however, that any replacement mission would have a severe impact upon the programme of missions sketched above. Specifically, timely and important missions such as the new medium-sized mission COBRA/Samba and the FIRST mission may be significantly delayed.

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[40] Not printed, deposited in the Record Office.

[41] *Government Accounting*, Vol II, paras 27.2.5 and 27.2.6 states one of the reasons for bodies to take out insurance is "to protect their livelihoods or businesses, because it would be beyond their financial ability to cope with a major and uninsured loss. Insurance in effect spreads the cost of losses over time, making it easier for individuals or businesses to manage their cash flows, and may for example avoid a major loss resulting in bankruptcy" and "The Government does not need to purchase insurance for the second of these reasons - ie to protect the viability of its business. The total size and range of the Government's business is so large that insurance on those grounds is not justified."

[42] *Ibid*, Paras 27.3.9 and 27.4.11.

[43] *Forward Look of Government Funded Science, Engineering and Technology*, Cm 3257-I, Table D2.

III. WHY FUND BASIC SCIENCE?

PPARC AND THE SCIENCE BUDGET

29. PPARC operates within the context of a limited science budget. In funding terms, it ranks third of the six research councils with an annual income for 1995-96 of £196.4 million.[44] Decisions about the correct level of funding for PPARC are effectively decisions about the funding which should be made available for the science it supports, particle physics, space science and ground based astronomy. Other Research Councils are also facing severe problems; for example, the Biotechnology and Biological Sciences Research Council (BBSRC) has been able to fund only one in five of responsive applications and has had to reject one in three of proposals which were rated as internationally important.[45]

30. PPARC funded science is often claimed to be "fundamental"; it is. But while new and exciting discoveries are being made in each of the fields PPARC funds, they only address one particular family of those problems which scientists see as fundamental. It is striking that, although some physicists think of physics as being a uniquely fundamental science from which in principle all other sciences can be derived, in practice this is not a fruitful line of attack. All key disciplines have to develop their own methods and results from their own observations, hypotheses and experiments. These will lead to the development of principles which are not necessarily derivable from the "fundamental principles" of particle physics, or of other disciplines, but which are of the greatest scientific importance. Thus, in practice, chemistry develops its own principles, which might be supposed to be derived from those of physics, but which often are not. Biochemistry cannot be strictly derived from chemistry, nor biology from biochemistry. Whilst particle physicists study the smallest and most primordial particles, knowledge of their processes may not in practice be helpful for the complex studies of matter in bulk which underpin, for example, the understanding of disease, the physical processes involved in the brain, or the delicate balance of life on our planet.

31. Allocating intellectual precedence to one branch of science over another is a complicated and controversial process, and we believe that it is unhelpful to try to do so. Such scientific ranking may be associated with claims for a certain level of funding; but funding decisions cannot be made on such grounds alone.

32. We believe that curiosity driven science should be better supported, but the level of that support cannot rest on the interest of the science for its practitioners alone. Social considerations are intimately involved in funding decisions; in the 1950s nuclear and particle physics itself benefitted from the interest engendered by the atom bomb and nuclear power.[46] There is a public perception that particle physics is no longer central to national interests in this way, while other topics such as medical or environmental research are. At present the CERN subscription alone is greater than total United Kingdom expenditure on research on the global atmosphere and marine sciences.[47] **Any positive recommendations about the future funding of PPARC should not be taken to imply a belief that other parts of the Science Budget should be cut to compensate for increases in expenditure on PPARC's budget.**

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[44] The other research councils' funding is as follows: Engineering and Physical Sciences Research Council £365.7m; Medical Research Council £277.8m; Biotechnology and Biological Sciences Research Council £162.0m; Natural Environment Research Council £155.5m; Economic and Social Research Council £61.2m. *Allocation of the Science Budget 1995-96*, OST 1995.

[45] Biotechnology and Biological Sciences Research Council, 1996-97 Business Plan, p54.

[46] See Margaret Gowing, *Independence and Deterrence: Britain and Atomic Energy*, 1945-1952, London 1974, Vol 2, passim.

[47] In 1995-96 the Department of the Environment spent £14.8m on research into the global atmosphere, and £3.3m on water and marine; NERC spent £7.2m on atmospheric science and technology and £40.5m on marine science and technology. (1996 *Forward Look*, Cm 3257-I, p56, p17).

THE VALUE OF BASIC SCIENCE

33. As many witnesses maintained, basic research should be funded because of its contribution to our culture. Researchers who did not work in fields funded by PPARC were happy to attest to the intellectual vitality of physics and astronomy.[48] The Department of Physics and Astronomy of University College London told us:

> "Since Newton and the foundation of the Royal Society, UK scientists have been a major force in forming the picture of the natural world and extending the boundaries of knowledge. Many of the important questions in contemporary particle physics and astronomy have been posed by UK scientists and some of the greatest experimental and observational achievements since the second world war have had strong UK input. Withdrawal from participation in the world's most ambitious programmes would close down one of the most vital components of our nation's intellectual life."[49]

34. Although hard choices have had to be made, and research in some fundamental areas has been severely reduced, the United Kingdom remains at the forefront of research in each of the fields covered by PPARC. The United Kingdom comes second only to the USA in the number of astronomy papers published and, in the last five years, astronomy papers written by United Kingdom researchers were cited more frequently than any others except those with US authors.[50] United Kingdom particle physicists are highly influential in international experiments, even though their level of funding is relatively low.[51] We were greatly impressed by the enthusiasm, commitment and ingenuity of the researchers we met on our visits. **We consider that withdrawal from fundamental research would, in effect, terminate the United Kingdom's claims to be among the most advanced nations of the world. Moreover, it would squander national expertise in one of the areas in which British research leads the world. It would also send a very negative message to young people considering scientific careers. We have no wish to see that happen.**

35. There are other, secondary, reasons for supporting astronomy and particle physics; they generate enthusiasm for science; they open up a realm of international co-operation and they produce considerable industrial benefits.

Public Interest

36. We believe it is essential that the public is aware of the excitement and challenge of science. Because they deal with big questions, particle physics and astronomy evoke a great deal of public interest. All our witnesses felt that these subjects played a crucial part in arousing and maintaining public interest in science.[52] In particular, the subjects play a key role in attracting young people into physics; once attracted, they branch out into many other areas of science.[53]

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[48] See, for example, QQ91-92, QQ124-129.

[49] Ev p115.

[50] Ev p63.

[51] Ev p63.

[52] See, for example, QQ10, 111, 136.

[53] Ev pp136, 138.

International Collaboration

37. The internationalism of PPARC science is also valuable. **We consider that international collaboration has a value over and above the scientific opportunities it affords. Most importantly, it fosters networks of highly skilled people; it gives British researchers and, potentially, British industry, access to the best research available.** Managing or participating in international scientific collaborations also gives the researchers involved valuable skills, which may be used within science or in other spheres. **The knowledge that international collaboration to investigate the depths of atomic structure or the further reaches of the universe is not simply possible, but is being triumphantly carried out, should act as a spur to collaborate on other more mundane problems which need international solutions.**

Spin Off

38. Even though our witnesses were clear that pure science should be pursued for its own sake and that it was inappropriate to justify research in astronomy and particle physics by the hope of gaining economic benefit from discoveries made therein, they were also adamant that such research did produce economic benefits, both directly, and in terms of spin off.[54]

39. In the pure sciences, many of the most important discoveries bring only long-term benefits to society. Dr John Hassard pointed out:

> "quantum mechanics was a result of physics observations made at what was then the Higher Energy frontier. Now it underlies virtually all physical science and much technology: nobody could have predicted its extent, or even existence in the late 1800s. All modern technologies like electronics, lasers, telecommunications, TVs etc are based on and *could not have existed without* the ideas of quantum mechanics."[55]

As the Director General of CERN remarked:

> "it would be rash to claim that fundamental discoveries in particle physics are likely to have direct applications. It is certain, however, that mankind will not be able to exploit facts and laws of nature that remain unknown!"[56]

40. There are also benefits which arise from the enabling technologies needed to conduct fundamental science. There are well over 10,000 particle accelerators in use today; only about 100 are used for particle physics. The others are employed in a variety of ways, including the manufacture of semiconductors, testing welds in crucial structures such as nuclear power stations and aero-engines, sterilising waste, and in medicine.[57] Accelerators are also now used in other parts of science, which are more directly applicable than particle physics. Professor Sir John Kendrew gave the use of synchrotron radiation as a fundamental tool in molecular biology as an example and remarked that "If [particle physics accelerators] had not existed, I would be surprised if there would be synchrotrons available now."[58]

41. It is impossible to quantify such benefits precisely. As Dr Hassard warned:

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[54] See, for example, Ev p173.

[55] Ev p149.

[56] Ev p176.

[57] Ev p174.

[58] Q98.

> "Spin-offs usually appear serendipitous, in which fundamental physics, by attempting to do intrinsically difficult things, produces opportunities in other fields, which are seized, and do not appear to be coming from high energy physics, because overlaid there is a huge amount of extra work by specialists in other disciplines and by technologists—but without the particle input could not have been conceived."[59]

It is, however, clear that particle physics has had a profound effect upon our every day life.

42. There are also many more indirect industrial benefits. All PPARC science relies on sophisticated equipment; space science and particle physics, in particular, require extremely high precision technology which can withstand extreme circumstances such as the chill of space, or the radiation found at times in a reactor. For example, accelerators are marvels of high engineering and applied physics. The pipeline in the tunnel of a synchrotron accelerator must circle tens of kilometres with a deviation of only a fraction of a centimetre. The magnets required to focus the beam of particles within the pipeline are intensely powerful and to produce the high magnetic field strengths necessary, superconducting magnets capable of sustaining huge currents have been employed. Their coils have to be cooled to a temperature of around 4 degrees Kelvin - four degrees above absolute zero (for comparison, freezing point is 273 degrees K).[60] This alone has meant that CERN has developed new techniques in geodesy (surveying), superconductivity and cryogenics. Some leading British companies, such as TESLA and Oxford Instruments, have been involved. Again it is impossible to tell how much spin off would have occurred if similar effort had been put into other high technology projects, but it is clear that CERN has had significant effects. The most notable of these developments is the World Wide Web, developed so that physicists in different countries could communicate with one another, which is considered likely to have vast economic and even social implications.[61]

Industrial Benefits

43. PPARC also produces skilled scientists, who are highly regarded by industry, for the skills in communication, problem solving, initiative and team working that they gain through working on collaborative projects.[62]

44. While scientists take a leading role in developing the technology needed for PPARC science they work in close collaboration with industry, and industry supplies most of the equipment ultimately developed. Industry's own technology base is significantly strengthened by working on such projects. Both CERN and ESA cited research[63] attesting to this and Logica confirmed CERN's findings that companies which gained CERN contracts increased their trade with other organisations as a result:

> "we have successfully commercialised the experience, techniques and technology used on ESA space science missions and applied them to commercial projects, and not only for space applications, but also for a wide variety of non-space clients."[64]

We will discuss the industrial policies of CERN, ESA and PPARC in more detail in the following sections.

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[59] Ev p149.

[60] Ev p175.

[61] Ev p172.

[62] Ev p45.

[63] Ev p173 and Annex III.

[64] Ev p146.

IV. MAJOR POLICY ISSUES

INTERNAL MANAGEMENT

45. We do not intend to comment upon PPARC's management of its programmes in any detail, even though we received a certain amount of evidence on the matter. Some witnesses identified shortcomings, notably in the way in which their subject was treated by comparison with other PPARC subjects, but, for the most part, witnesses felt that PPARC was making a reasonably good job of setting up new structures and dealing with limited resources.[65] There was only one point on which both particle physicists and astronomers were agreed; this was that PPARC Council was deprived of valuable expertise because the Chairmen of the Particle Physics and the Astronomy Committees were no longer ex-officio Members of PPARC's Council. It has now been decided that the Chairmen of these Committees will attend Council "whenever there is relevant business".[66] We trust that this will be an effective way of ensuring that Council has the expertise it needs and that communication with the research communities is as effective as possible.

INTERNATIONAL ORGANISATIONS

46. All witnesses were adamant that the PPARC programme would be impossible to run without membership of CERN and ESA,[67] which gave access to facilities which would be far beyond the United Kingdom's own resources. Countries with their own space science programmes, such as France, or their own particle physics programmes, like Germany, were also committed to these organisations. However, there were concerns that the programmes of CERN and ESA, and the efficiency with which they were conducted, had significant effects on PPARC's domestic programmes.

CERN

47. Almost all those who commented believed that CERN was an impressively well run organisation.[68] It has managed a series of large projects efficiently within a budget which over the last twenty years has shown little increase above that which could be accommodated by the inclusion of new member states.[69] It has held down the cost of new accelerators by re-using previous ones; for example, the Proton Synchrotron and the Super Proton Synchrotron currently in use at CERN will be used to accelerate particles before they are injected into the LHC.

48. In particular CERN procurement is not distorted by 'juste retour' — the practice by which Member States are awarded contracts in proportion to their subscriptions. The CERN management is however making efforts to ensure that contracts are not disproportionately awarded to companies in particular states. They do so by inviting unsuccessful companies in states which have relatively little business with CERN to match or better a low tender from countries which regularly secure a higher proportion of contracts.

> "Calls for tender are preceded by market surveys in the Member States. These cover many more firms than in the past, but for the subsequent tender, the number of companies contacted is limited. These two measures give CERN better control over where its contracts go. If the lowest bid after a call for tender comes from a company in a Member State

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[65] See, for example, Ev pp2, 87, 89, 90, 95, 97, 99, 103, 147, 155.

[66] Q252.

[67] See, for example, Ev pp1, 86, 90, 94.

[68] See, for example, Q160, Q164, Ev p3, 88, 90, 92, 96, 105-6, 120-1, 139, 143.

[69] Q149, Ev p163.

> which is already doing good business with CERN, companies in other Members States are given the opportunity to align their prices to the lowest bid and thereby win the contract."[70]

This has the effect of reducing costs to CERN, as well as allowing technically competent companies in all member states the opportunity to extend their customer base through working at CERN.

49. This is not to say there is no room for reductions in CERN's costs; some witnesses felt that the organisation could be more efficient and in particular that salary costs were excessive.[71] In 1995 the United Kingdom, Germany and Italy voted against an increase in CERN salaries, which account for about half the CERN budget.[72] CERN stated:

> "In considering CERN salaries ... it is necessary to (i) note that 65 per cent of recruitment is from industry, and that CERN must be able to recruit from Member States with the best employment conditions if it is to be a genuinely international organisation, (ii) take account of purchasing power parities (which differ greatly from the exchange rate for £/Swiss franc comparisons), and (iii) bear in mind that CERN salaries have been pushed below those of other international organisations in Geneva, as well as international scientific research organisations elsewhere, such as ESO, ESA and EMBL."[73]

Clearly, the British Government was not wholly convinced by these arguments and nor are we. Although the salary increase was agreed to, on the votes of other Member states, there was agreement to recruit more short term fellows and associate scientists at lower grades in the future, which may keep salary costs constant.[74] This would also enhance CERN's already international nature by allowing a "greater throughput of established and younger European scientists."[75]

ESA

50. We believe that ESA has an impressive record in space science, and in space activities in general, and Britain's membership should not be in any doubt. However, over the last decade the ESA subscription has risen by 51.9 per cent in contrast with CERN's 9.2 per cent.[76] A large part of this rise is due to real increases in the ESA science activities and the ESA subscription paid by PPARC is far lower than that to CERN. Even so, it is not unreasonable for the Government and PPARC to seek to contain ESA expenditure.

51. There was widespread concern that ESA was not as efficient as it should be.[77] Most criticism was directed at the general management since it was generally held that the 1989 Pinkau Review of the management of the science programme had already resulted in greater efficiency. However, some well-informed witnesses believed that even the management of the science programme could be improved still further.[78] Measures have already been taken to force such improvement. The Ministerial Council in Toulouse in October 1995 imposed a 3 per cent annual efficiency savings cut on the ESA science programme budget.[79] Reform

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[70] CERN 1994 Annual Report, Vol 1, p35.

[71] Ev p44.

[72] *Nature*, Vol 378, 21/28 December 1995, p758.

[73] Ev p164.

[74] *Nature*, vol 378, 21/28 December 1995, p758.

[75] Ev p150.

[76] See Annex I, Table 3.1.

[77] QQ82-83, Ev p1, 122, 133-134.

[78] Q77-78, Q82.

[79] Ev p42.

of other ESA programmes is also expected.[80] We agree that the United Kingdom should seek to improve efficiency wherever possible, and that the science programme should remain under proper scrutiny. However, it is also important to ensure that the space programme does not become the sole focus for reform simply because it is the one area in which expenditure is mandatory, and to be alert to the possibility that reforms in one area, such as ESA's general expenditure, could have knock-on effects on the space budget.

52. ESA operates on a principle of proportionality; a country will be given a share of ESA contracts roughly proportional to the amount it contributes to a particular programme. (This does not apply to the scientific instruments in the science programme; indeed, one of the reasons why they are not directly funded by ESA is to allow scientific competition between ESA partners).[81] Although United Kingdom companies appear to be highly regarded for their high technology expertise, their share of the work will always be restricted. The ESA treaty gave a lower limit of the return co-efficient to each country of 0.8; it has crept up to 0.96.[82] A return to the original co-efficient might open new opportunities for British industry, although there is no certainty of this. It would certainly help in reducing ESA's costs and should be supported for this reason alone. Dr Bonnet, the Director of the Science Programme at ESA, told us that a study on the commissioning of Cluster in which the principle of proportionality was relaxed suggested that savings of 10% could be achieved.[83] This could well be an underestimate. There is currently an ESA working party on the subject;[84] when it reports to Council, the Government should judge its proposals by the extent to which they reduce ESA's costs and increase its efficiency.

53. Some form of juste retour may always be a feature of a collaborative project such as ESA. However, there is a further reason for opposing the excessive use of juste retour. Although it gives European companies a protected market within ESA, as the DTI draft Forward Plan makes clear, it hinders them "from becoming competitive on the international market, one of ESA's duties in the Convention."[85]

Relations with International Organisations

54. We agree that PPARC and the OST should, wherever possible, seek to improve the efficiency of international organisations. However there was some concern that this drive for efficiency could be conducted in such a way that UK influence was reduced. Professor David Southwood, of Imperial College, noted

> "It is clear that ESA needs to change and one wants to see some of the UK's wishes on efficiency effectively introduced. However it is not clear what is the most effective approach. My own prejudice is to be diplomatic but to be clear-sighted over what is needed. We may reduce our contribution to the programme faster in the way we have been going recently but we will also reduce our return by this means; it is not a way to win influence."[86]

55. Although the pressure for improvement should be maintained the UK could perhaps do more to present itself as an enthusiastic and whole hearted member of CERN and ESA; after all, our activities in particle physics and space science are almost entirely dependent upon

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[80] Ev p44.

[81] Annex III, plviii.

[82] BNSC, *UK Space Policy - a draft Forward Plan*, p28.

[83] Annex III, plvii.

[84] *Ibid.*

[85] *UK Space Policy - a draft Forward Plan*, BNSC, June 1996, p28.

[86] Ev p134.

them. There are worrying indications that the United Kingdom is losing influence; Dr Bonnet told us that when PPARC was formed "there was a sudden change from a regime where the UK had real influence... to one where the UK delegation has suddenly been isolated" even though individual scientists maintained their high standing.[87]

56. The United Kingdom's representation at ESA has not changed significantly since PPARC was established. The United Kingdom is represented at ESA Council meetings by the Director General of the British National Space Council (BNSC). When there are matters of science to discuss PPARC delegates have the right to attend and speak. We were told that "Over the past two years this role has been undertaken primarily by the PPARC Director of Science, Dr Ian Corbett."[88] The Chief Executive has attended twice. At ESA's Space Programme Committee the United Kingdom is represented by Dr Paul Murdin, PPARC Head of Astronomy, and Professor Mike Cruise, Chairman of the PPARC/BNSC Space Advisory Panel. Professor Pounds told us that "it is open for me personally also to attend ... and this I do occasionally."[89] He also remarked "...it is not thought that I am quite the right sort of person to be a delegate."[90] As we have already noted, one of the first actions of the Chief Executive was to take responsibility for telling ESA that the UK was not able to participate in the INTEGRAL mission.[91] It was courageous of him to do so. The United Kingdom delegation to the CERN Council consists of the Chief Executive of PPARC, who leads it, and the Director of Research Councils from the OST. This is a change since the days of the SERC, when the Chairman of the Council and the Chairman of the relevant Board attended. The Chief Executive has attended three of the four Council and five of the eight Committee of Council meetings held since PPARC was established and "went to every meeting on the critical run up to the selection of the LHC in December 1994,"[92] when the United Kingdom and Germany were trying to ensure that the costs of the project were contained.

57. Liaison with CERN and ESA is one area in which the Chief Executive of PPARC should take a lead. **We consider that it is important that those at the highest level should be seen to take a close and continuing interest in CERN and ESA, even if they are not best placed to deal directly with all the business conducted there. It is unfortunate that the Chief Executive's visits to these international organisations have largely taken place when budgets were being negotiated or when bad news had to be delivered.**

Promotion of High Technology Industry

58. As we have seen, astronomy and particle physics play an important role in forcing the development of high technology industry. The importance of cutting edge science in developing entire industries can be seen in the European Space Agency. As the BNSC discussion document on Space Policy said:

> "The scientific ambitions to gather the largest possible flux from distant, faint, astronomical objects, or to carry out complex experiments in distant parts of the solar system, drive the need for innovative technology. The ESA Horizon 2000-plus space science programme is explicitly built on technology foresight to identify and stimulate in Europe the development of new technologies needed for 2010 and beyond. Thus, in addition to being a scientific success in the UK, the Space Science programme has developed UK industrial expertise in space. PPARC funds industrial contracts totalling over £30m per annum in the UK, via the

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[87] Ev pp139-140.

[88] Ev p181.

[89] Ev 180.

[90] Q235.

[91] Q238.

[92] Q235.

> ESA subscription. These developments for Space Science missions read across to Earth Observation and industrial space applications, as well as attracting, motivating and stimulating the industry's employees."[93]

59. ESA was established to ensure that Europe had a distinct and coherent space capability. It is ESA's policy to spin out mature industries. For example, an independent company, Arianespace, now conducts commercial launches and has sixty per cent of the world market. Indeed, Arianespace has grown so successful that ESA is now attempting to ensure it shares in the costs of developing new launchers.[94] Other opportunities for spin out will arise and should be actively pursued.

60. Industry was strongly supportive of the United Kingdom involvement in space.[95] Indeed, Logica was concerned that too little attention was paid to the industrial implications of decisions about whether or not to join optional programmes:

> "In recent years, ESA has introduced various optional technology programmes. The optional nature of these programmes means that countries can choose to contribute as much or as little funding as they wish. In general, the UK has opted to contribute little if any funding to these programmes.
>
> Increasingly, these optional ESA technology programmes are being used to fund technology relevant to space science programmes. Since the UK largely opts out of these technology programmes, UK industry is finding it increasingly difficult to stay abreast of the technology required for future space science missions."[96]

61. On 24th June the BNSC published *UK Space Policy - a draft Forward Plan* which set out "aims and actions for the UK civil space programme ... developed in consultation between BNSC partners, industry and academia."[97] The Government also announced increased funding for European Space Agency programmes, including £2m for the General Technology Support Programme.[98] **We welcome the Government's initiative in putting forward a coherent long term strategy for Britain's space activities. We support its proposals for ensuring that both national policy, and collaboration with ESA, are designed to strengthen industry and make it internationally competitive. We hope this will lead to benefits for the overall space programme as the private sector increasingly becomes able and willing to provide some of the finance for its activities. We trust the new policy on space will ensure that in future the United Kingdom will participate in technology development programmes at an appropriate level.** The draft Forward Plan envisages increasing use of the Private Finance Initiative in space activities. Space science is of course not obviously suited to the PFI. However the companies which enthusiastically support involvement in ESA programmes might consider whether they value them significantly enough to make some contribution to their costs.

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[93] *Space Policy - a discussion document,* December 1995, para 32.

[94] Annex III, plv.

[95] Ev p121, 143, 145.

[96] Ev p146.

[97] p2.

[98] In addition satellite navigation received £3.6m and applications £1.5m.

Industrial Liaison

62. Although PPARC science is not directly applicable and the ROPA scheme, designed to reward researchers for collaboration with industry, cannot be used in PPARC, the Council has been active in encouraging industry to benefit from it. We were told:

> "In its first year PPARC launched a new scheme to support industrial collaboration — the PPARC Industrial Programme Support Scheme (PIPSS) — which attracted a high level of interest. Despite a short deadline some 47 applications were received from some 25 different industrial companies and a similar number of academic groups. The list of successful awards, included in the Annual Report, indicates the range of topics and companies covered. A second round of PIPSS, completed more recently, resulted in a similarly strong response.
>
> In parallel the Council has been advised by its Industrial Liaison Panel (50 per cent industrial, 50 per cent academic members) on a number of ways to enhance industry's awareness of novel technology generated in the Council's programmes and how to increase further its flow into industry. These range from the development of a long range technology plan to the support of industrial PhD training such as an enhanced CASE (Co-operative Awards in Science and Engineering) scheme, and use of the Internet to spread awareness of university technological expertise."[99]

63. In addition, in the past PPARC, the DTI and the EPSRC funded a liaison unit which dealt with the Institut Laue Langevin (ILL) and the European Synchrotron Radiation Facility (ESRF) as well as CERN.

PPARC told us:

> "The DTI part-funding for the Unit finished at the end of its 3 year grant in June 1995. PPARC, DTI and EPSRC (who were also partners as the Unit addressed ILL and ESRF) had long discussions on the future of the Unit when it became clear that it would not become self-financing through industrial subscriptions, as had originally been hoped by DTI. PPARC and DTI tried hard to find a means of providing funding for a future activity that would serve the needs of PPARC, in fulfilling its strategic objectives, of CERN and of industry. Eventually PPARC decided to go ahead and establish its 'Unit for CERN' at CLRC. DTI decided not to contribute to this and neither have EPSRC. Hence the new Unit does not address the needs of industry relating to ILL and ESRF."[100]

64. This lack of continuity may have affected British industry's ability to win contracts at CERN. Professor Llewellyn Smith told us that the United Kingdom's return (in the form of industrial contracts) from CERN had dropped in 1995 and this "is thought to be a fluctuation due partly to a reorganisation of the UK structure responsible for strengthening and maintaining industrial links with CERN, and to the simultaneous reduction in funding for this activity, into which other Member States put more effort."[101] Almost all the evidence we received from industry strongly supported Britain's involvement in the research PPARC funded,[102] not least because of the benefits it brought to the companies involved in building the machines and instruments required in CERN and ESA. It is disappointing that industry would not bear a share of the costs of industrial liaison.

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[99] Ev p46.

[100] Ev p84.

[101] Ev p168.

[102] See, for example, Ev pp118, 121, 145.

65. We endorse PPARC's efforts to improve industrial liaison; it is proper that the Research Councils try to ensure that industry is aware of the benefits their work may bring, and PPARC is no exception to this principle. However, we are concerned that the withdrawal of EPSRC and the DTI from industrial liaison arrangements has left PPARC to provide the £20,000 pa needed for liaison with CERN from its own resources, while the coverage of the unit has been diminished. **We consider it would be appropriate for the DTI to provide at least some of the funding necessary for industrial liaison, since it is the department charged with promoting technology transfer.** Its failure to bear part of the cost will provide ammunition to those who claim the transfer of the OST to the DTI is likely to distort Research Council priorities.

PPARC'S FINANCIAL POSITION

66. Astronomy and particle physics have been under financial pressure for some time; the amount allocated to them by the Science and Engineering Research Council (SERC) had been declining. However, this decline was less obvious than at present because SERC itself decided how much to allocate to them and could, to some extent, deal with short term perturbations within its total budget. It is possible that this freedom meant that the subjects were not considered as dispassionately as might have been desirable but their share of the science budget was decreasing nonetheless. The foundation of PPARC has meant that decisions about the amount of funding to allocate to particle physics and astronomy are now taken by the Minister for Science and Technology on advice from the Director General of Research Councils rather than being decided within the SERC. Since the new system was introduced there appears to have been much less inclination to vary this amount in response to short term pressures.

67. In the course of our inquiry, the pressures on the PPARC budget became so great that the PPARC Council decided that radical action was needed. Council decided that reducing investment uniformly across the programme was no longer cost effective; rather, to protect the astronomy programme, particle physics expenditure was to be capped; extra resources for particle physics were to come, if at all, from renegotiation of the CERN budget, to be carried out by PPARC and Government to ensure that, in sterling terms, the United Kingdom's contribution remained steady at £66.5m.[103] This business plan was submitted to the OST at the time the Committee was preparing its Report. We will return to it later, but the first question must be, how did the PPARC programme and the resources available to it come to be so mismatched?

68. It is very difficult to construct consistent data for expenditure on PPARC subjects over even the last decade. The reorganisation of the Research Council system, and the transfer of money for some research overheads from the Higher Education Funding Councils to the Research Councils (the "dual support transfer") means that there are significant discontinuities in the published data and significant differences in the data derived from different sources. We have accordingly, with PPARC's assistance, compiled our own tables, using PPARC's internal data, which we believe gives a more accurate picture. These are printed as Annex I to this Report. This uses the appropriate Research and Development figures from SERC and from PPARC; it does not include the dual support transfer, administration and programme support, public understanding of science or studentships and fellowships. For comparison, we have also printed the other time-series which have been made available to us.[104] The difficulties in using previously published data are cause for considerable concern, and should be a source of embarrassment to at least some of the bodies concerned; but the conclusions we draw remain valid irrespective of which set of figures we use. We are particularly

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[103] *Business Plan* 1996, PPARC.

[104] See Annex I, Ev pp52, 53.

concerned that the 1996 Forward Look gives the CERN subscription as £69.5m.[105] In fact, as the PPARC Business Plan makes clear, the subscription due in 1995-96 is £66.5m. However, an additional payment of £3 million was paid in 1995-96 towards the subscription for 1996-97.[106] By failing to distinguish between the two figures the Forward Look fails to give an accurate representation of the cost of CERN. **We hope that the compilers of the Forward Look and its Statistical Supplement will bear in mind that one of the functions of such publications is to allow comparisons to be made over time, and will accordingly ensure that in future statistics are comparable from one year to the next.**

69. PPARC provided figures in the course of its evidence which used a twenty year scale. At the beginning of this period two national accelerators were running in the UK. These were closed and "the entire experimental programme was transferred overseas, principally to CERN."[107] There is consequently a rapid decline from the 1975 baseline used by PPARC which in our view renders the use of that baseline inappropriate; the decision to close down the national accelerators fundamentally changed the nature of the particle physics programme, and this fact must be recognised. We have accordingly used 1985-86 as a baseline for comparison.

70. The transfer of astronomy[108] and particle physics[109] spending from the former SERC to PPARC appears to have been conducted fairly; there was a slight reduction in the real resources allocated to PPARC Research & Development expenditure in 1994-95 by comparison with that allocated in 1993-94, but this was a year in which the cost of international subscriptions had in fact fallen. An increase in the money allocated to PPARC's R&D in 1995-96 meant that, in real terms, the total amount of R&D expenditure available to PPARC was only a little less than that available in 1985/86.

71. It is misleading simply to look at the figures for PPARC alone. The university sector provides significant support for astronomy and particle physics, both in university appointments and some post-graduate scholarships and in other less direct ways, such as providing basic scientific equipment. The Dual Support transfer appears to have failed to compensate particle physics adequately, at least in the first year.[110] Nearly £2 million appears to have been removed from the university support for particle physics without being transferred to PPARC. This was over ten per cent of the total SERC spending on domestic particle physics research. It is difficult to guess the long term effects of the transfer; it is, in principle, possible that PPARC's allocation would have been smaller if more money had been flowing from the universities, but this was a large initial reduction coinciding with a transfer which was supposed to have been neutral in its effects. PPARC believes that astronomy also suffered a reduction in total funds available, although this effect was less marked.[111]

72. However, the dual support transfer is a relatively minor factor in PPARC's difficulties, and is excluded from the figures we have used. The two major causes are a rise in international subscriptions, and a need to invest in the increasingly expensive equipment, particularly the LHC experiments, and missions which will supply data in the future.

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[105] p18.

[106] p28.

[107] Kendrew Report, para E3.

[108] PPARC's Astronomy and Planetary Science is equivalent to the SERC's Astronomy and Planetary Science less Earth Observation.

[109] PPARC's Particle Physics is equivalent to the SERC's Nuclear Physics less Nuclear Structure.

[110] Ev p180.

[111] Not printed; deposited in Library.

International Subscriptions

73. PPARC divides its funding into "Domestic" and "International Subscriptions" although the second category in fact comprises only the CERN and ESA subscriptions and the domestic line includes a further £38.6m in spending on international facilities. PPARC explained:

> "ESA and CERN subscriptions are always identified separately as 'International subscriptions' both because they are the subject of inter-governmental treaties over which we have no direct control, and because they are reported to Government separately and cannot be vired with other subheads."[112]

As PPARC says "the majority of our work can be carried out only in international collaboration";[113] a rigid distinction between domestic and international would be highly misleading. The CERN and ESA subscriptions are far higher than the only other comparable expenditure (on the Anglo-Australian telescope) and the facilities they provide are central to PPARC's programme. In the last ten years domestic expenditure has declined while international subscriptions have risen by 22 per cent. They now account for some 54 per cent of PPARC's budget.[114]

74. Domestic expenditure on astronomy has fallen by 15 per cent, although increases in the ESA subscription have meant the *total* expenditure on astronomy has increased. Although the ESA subscription has risen consistently, the ESA space science programme has expanded in real terms. However some at least of the 52 per cent rise over the last decade has been caused by non-programme factors such as exchange rate fluctuations.[115]

75. The decline in domestic particle physics expenditure has been still more marked. In 1984 the SERC and the Advisory Board for the Research Councils commissioned a Report on High Energy Physics in the United Kingdom (the Kendrew Report). This concluded that although particle physics research was of the highest quality, it absorbed too great a portion of the science budget and recommended that expenditure (including the CERN subscription) should be reduced by 25 per cent. In the last ten years the spend on domestic particle physics has declined by about 35 per cent, as against the 15 per cent decline of astronomy. This has not been a steady, gradual reduction; there have been quite marked year on year fluctuations, but the general trend has been clear. Yet the sterling cost of the subscription to CERN has risen by 9.2 per cent in real terms over the period, even though in Swiss francs it has been stable or falling. *Total* expenditure on particle physics, including the CERN subscription was £92.7m in 1985-86 (at 1995-96 prices), the year of the Kendrew Report; in 1995-96 this figure was £87.1m, an overall decrease of 6 per cent.

76. The CERN subscription is the larger of the two, and the one which causes most concern. It has fluctuated widely; indeed, in 1994-95 at £59.9m it was lower in real terms than it had been in 1985-86. However, it has since risen steeply and £71.8m is allocated for it in the current financial year (1996/97).[116]

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[112] Ev 177.

[113] *Ibid.*

[114] Ev, p38 (PPARC's figures); see also Annex I, Table 1.2.

[115] Sir John Cadogan said the subscription had risen £2 million in 1995-96 'because of currency fluctuations', Minutes of Evidence, 24 January 1996, HC 175, Q105.

[116] *Forward Look of Government - funded Science, Engineering and Technology*, OST 1996, Cm3257-I, p18.

Reasons for Changes in Sterling Levels of International Subscriptions

77. There are two reasons for this fluctuation; alterations in exchange rate, and changes in the relative Net National Income (NNI) of member states. First, a decline in the strength of sterling will, to some extent, increase the amount of sterling needed to purchase the Swiss Francs required for the subscription. In 1990 the system for calculating the subscriptions was changed since there were concerns that long time lags in the figures used to calculate the subscription could be unfair, particularly to countries entering recession after a period of prosperity, and the system was sensitive to exchange rate fluctuations.[117] However, even this new system could not prevent increases in subscriptions if all currencies fell against the Swiss Franc, as has happened in the past few years. Second, CERN contributions are based on the Net National Income of each Member state; in the past few years the United Kingdom economy has been stronger than those of many of the partners in CERN and the United Kingdom's absolute share of the budget has consequently increased. Professor Llewellyn Smith calculated that nearly half of the increase in subscription was due to this.[118] This part of the increase in the United Kingdom contribution is likely to have peaked since other European countries are now emerging from recession, and the relative strength of the United Kingdom NNI will decline.

Payment of International Subscriptions

78. Increases in subscriptions have a direct effect on the domestic programme. PPARC claimed:

> "Alone among member states, the UK has traditionally funded its intergovernmental science subscriptions from the same budget as the funds needed to exploit those subscriptions. While this funding method has logic, the effect has been that, as subscriptions have risen, the supporting domestic budgets have been cut".[119]

In fact, the situation appears slightly more complex. The House of Lords described the systems used in France and Germany in their 1991 Report on international scientific programmes. From this it appears that the science ministries of each country have an important role in negotiating the budget, and that they take the level of international subscriptions into account when doing this. However, in both countries, the effect of currency fluctuations at least appears to be covered by the Treasury.[120] We put this discrepancy to PPARC which maintained:

> "To the best of our knowledge, the general principles described in [the House of Lords'] Report remain true, although in both Germany and France the names and some responsibilities of the ministries concerned have changed.
>
> In both cases the international science subscriptions form part of much larger budgets covering a range of other large subscriptions. While future budgeting pressures on the subscriptions may start to impinge on domestic budgets there is little evidence of this effect to date, and as we have shown in our Supplementary Memorandum, their levels of domestic expenditure remain several times the size (pro-rata to NNI) of ours."[121]

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[117] POST; *The Nature of Matter: International Collaboration in Particle Physics* p16.

[118] Annex II, pli.

[119] Ev p43.

[120] Second Report from the Science and Technology Committee, *International Scientific Programmes*, HL(1990-91)24-I, paras 8.22-24.

[121] Ev p180.

79. Since 1995, the United Kingdom has moved to a system closer to those of other countries, by top-slicing the Science Budget to make allowances for fluctuations in international subscriptions caused by exchange rate changes or relative economic growth. The 1994 subscription is currently taken as the baseline above which such fluctuations are compensated.[122] However, although this system shields PPARC from the worst effects of the fluctuation, it cannot remove them entirely. Professor Pounds claimed that not only had PPARC suffered the loss of its share of the £10m withheld for currency fluctuations, it was unlikely to receive additional money in the course of the year, since the "top sliced" section of the science budget was seen as directly attributed to it.[123] The new system also fails to protect the Science Budget as a whole from such fluctuations and has been accused of causing resentment among scientists of other disciplines.[124]

80. In principle, the Public Expenditure Survey negotiations should provide an opportunity for the Science Budget to be compensated for anticipated increases in NNI. The OST has told us:

> "It is not Government policy to disclose the details of negotiations between departments and HM Treasury in the Public Expenditure Survey, but such pressures will clearly feature."[125]

81. There must be some suspicion that if the Science Vote were normally compensated for anticipated increases in NNI, the Government would announce this in order to take credit for it. There is certainly no clear commitment to compensating the Science Budget for increases in international subscriptions caused by improvements in the United Kingdom economic situation. Moreover, PES negotiations may not take account of the substantial fluctuations in exchange rates each year.

82. PPARC urged that international subscriptions should be completely removed from the science budget.[126] In contrast, *Realising our potential* set out Government policy as follows:

> "It is the Government's view that it is important for such subscriptions to be seen as part of our scientific endeavour rather than our foreign policy. Decisions on relative priorities must be taken in the context of the science budget."[127]

The problem inherent in this argument is that most of these subscriptions are determined by treaties negotiated at inter-governmental level, and it would not be open to the scientific community alone to withdraw from such treaties even if its members wished to do so. Moreover, it does not aid efficient planning to have substantial sums retained to deal with this problem each year. In the current year £10m has been topsliced from the science budget to meet the increase in the CERN subscription, in addition to £8 million carried forward from the previous year. **Like our colleagues in the Lords who examined this problem in 1991, we believe that it is inappropriate for the Science Budget to bear the costs of fluctuations in international subscriptions.**

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[122] Ev p177.

[123] Q193.

[124] Ev p140.

[125] Ev p177.

[126] Ev p179-180.

[127] Cm 2250, para 6.17.

Future Programmes

83. The United Kingdom has a strong presence in particle physics and astronomy, and this strength can only be maintained through taking part in international collaborations. However, the price of access to shared facilities must be loss of complete control over the programme. Consequently, PPARC is faced with a number of scientific opportunities which have become available at the same time. The Large Hadron Collider is the most obvious, but there will be investment in the JET-X instrument in 1996 and the X Ray multi-mirror mission, among others, in ESA.[128] The schedule for major ESA missions or the LHC is not within PPARC's control, although it may have some influence.

84. Since PPARC is considerably smaller than the SERC, it has far less flexibility in scheduling its expenditure. The difficulty was recognised by Sir David Phillips[129] in his boundary study of the Research Councils:

> "I note that the programme of PPARC relies very heavily on international collaborations, with more than half its financial resources being devoted to the payment of subscriptions which secure access to facilities, but which do not provide for their exploitation. In addition, much of the domestic programme comprises long-term commitments (for example, to space missions), with lumpy expenditure profiles that may cause handling difficulties within a budget that is significantly smaller than that of SERC. The new Director General may wish to consider with the PPARC's Chief Executive possible measures to help alleviate such planning difficulties."[130]

85. New missions or new accelerators do not affect the size of the subscriptions to CERN and ESA alone. If United Kingdom scientists are to participate fully, money has to be found in the domestic programme to finance the instruments required to take advantage of the new equipment. Without such instrumentation, the scientific programme will wither. The expectation is that these expensive instruments will provide data for the research community to work on for many years. PPARC noted:

> "Severe funding pressure on PPARC's domestic budget is now limiting future investment which will increasingly threaten the health of these research communities into the next century."[131]

86. PPARC has prepared an "optimised value for money programme" showing the cost of enabling it "to meet fully its strategic objectives" and to exploit international opportunities. This programme would cost some £20m more than the current plans for 1996/97, and would require over £40m more than is currently planned in 1999/00.[132] PPARC will never be able to take all the opportunities available to it; just as other Research Councils do, it will need to prioritise its programme within available resources. However, the nature of PPARC science, in which a large community needs access to extremely large facilities, means that "in most people's career, opportunities for any particular mission come infrequently. There will be no alternatives to Integral, the LHC or the Rosetta programme for British scientists."[133] The choice between missions is accordingly more difficult.

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[128] Ev p42.

[129] Former Chairman of the ABRC; now Lord Phillips of Ellesmere.

[130] Quoted in Ev p178.

[131] Ev p42.

[132] *Business Plan 1996*, PPARC p20.

[133] Ev p134.

The LHC

87. The most expensive of these new opportunities is the LHC. The decision to go ahead with the building of the LHC was taken by the CERN Council which is composed of representatives of all member states. The United Kingdom delegation included a representative of the OST as well as of PPARC. The Director General of the Research Councils told us that "Government policy is that we must take part in this great experiment".[134]

88. It is hard to imagine that PPARC would not have wished to participate in the LHC, which will dominate particle physics for the next twenty years. There will be no equivalent facilities, and no alternatives which will offer even comparable interest. However, the cost of the LHC is now threatening PPARC's domestic programme. The Director General of Research Councils told us that the United Kingdom was to enter negotiations to contain the level of the CERN subscription.[135]

89. The LHC budget was agreed some eighteen months ago, in December 1994. Although, in principle, each state's vote is of equal weight, Professor Pounds made it clear that the largest contributors, of which the United Kingdom is one, had the greatest influence.[136] Moreover in 1994 Council agreed to a double majority procedure, which would apply until the Large Hadron Collider was completed. Most recommendations from the Finance Committee now have to be agreed by states responsible for a least 70 per cent of financial contributions.[137] The United Kingdom and Germany made strenuous attempts to reduce the cost of the LHC and succeeded in securing a budget which would involve no increases in member states' contributions before 1998 and would restrict them to less than the level of inflation thereafter. In addition, France and Switzerland agreed to make additional contributions to CERN in recognition of the advantages they gained from hosting the facility. To enable the LHC to be constructed within a constant CERN annual budget, the collider was to be built in two stages; it would run with two thirds of the superconducting magnets in place from 2004 and be upgraded in 2008.[138] Despite these economies, there was no reduction in the United Kingdom's subscriptions to CERN and so no additional resources available for the provision of scientific instruments.

90. CERN operates an open access policy; currently some thirty per cent of CERN's users come from non-Member states, and this is expected to rise to around forty-five per cent at the LHC.[139] These scientists contribute to the building and operation of the detectors, but their countries currently pay nothing toward the accelerators themselves.[140] CERN is however seeking contributions from these non-member states toward the LHC. As the CERN Council agreed, these contributions will be used to bring forward the completion date of the project, from 2008 to 2004 or 2005, rather than to reduce the cost to member states.

91. The United Kingdom can only obtain full scientific value from the LHC if PPARC is able to fund the detectors associated with it. Otherwise, as Dr Sue Ion, a director of BNFL and a member of PPARC Council, said, it is like "paying an expensive membership fee of

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[134] Minutes of Evidence, 24 January 1996, HC 175, Q111.

[135] HC 175, QQ97, 108, 114-16.

[136] Q236.

[137] This procedure applies to recommendations relating to the Bannier procedure, the annual budget and the cost-variation index. CERN/2074/Final.

[138] Annex II, pl.

[139] Ev p167.

[140] The largest contingent come from the US, and the second largest from Russia. While the US users do not contribute to the CERN infrastructure, the Director General told us: "The Russian users include a significant number of engineers and applied physicists whose presence at CERN replaces staff effort and should be counted as a contribution to the laboratory." Ev p167.

a health club only to find I couldn't afford the few pounds court fee and racket rental each time I wanted to play squash."[141] In such circumstances the fee becomes a subsidy for other users, both members and guests. It is not possible to quantify the necessary resources exactly, but PPARC has put in a bid for extra resources (in £m) over the years 1997-98 to 2004-2005; it totals £65.5 million over the eight years, divided as follows:

1997/98	1998/99	1999/00	[2000/01	2001/02	2002/03	2003/04	2004/05]
2.00	4.50	10.00	[13.00	12.00	9.00	8.00	7.00[142]]

PPARC has said that, if necessary, it will match these increases by reductions after the LHC has been completed. We stress these are PPARC's figures; we believe that PPARC's requirement for extra resources will be intimately linked with other decisions about the timing and funding of the Large Hadron Collider. The cost of the LHC was reduced by 1 billion Swiss francs in the course of the negotiations in 1994. PPARC's bid would appropriate the United Kingdom's share of this reduction for particle physics.

92. It is true that PPARC's bid for additional resources would not have been so great if the sterling cost of the CERN subscription had stayed at the level of 1994-5. Although increases in the cost of CERN and ESA subscriptions above the 1994 baseline are now borne by the science budget as a whole, PPARC's share of that top slicing amounted to some £1.7m[143]. This sum, however, is trifling compared with the costs projected for detectors, which were foreseen by PPARC even before the agreement to fund the LHC was made.[144] It seems unlikely that the original plan of building the machine in two phases would have significantly reduced these costs, since the main part of the detectors would have had to be in place in 2004, when the LHC began operation, albeit at reduced power.[145]

93. PPARC had warned about the cost implication of the LHC in both the 1994 and 1995 *Forward Look*. When no additional resources were made available through the CERN negotiations, PPARC could only submit additional bids for resources to the Director General of the Research Councils as part of the process by which the Science Budget is allocated. These have clearly been unsuccessful. In any event, for the first time central government was officially represented at CERN, and the OST must have been aware of these problems. It is possible that when the LHC was agreed the OST expected a consequent increase in the science budget as a whole or that it expected at that moment a shift in resources towards PPARC and away from other Research Councils, which has not happened. The actual result has been that the CERN subscription will increasingly become a subvention of international science, of very restricted value to British science. As PPARC says, if the imbalance between domestic expenditure and international subscriptions continues "effectively it would mean the UK tax payer subsidising other nations' scientific research."[146] **We are concerned that the United Kingdom is now proposing to renegotiate an international agreement on grounds which should have been apparent at the time the agreement was first reached. Nonetheless, it is also a cause for concern that even under the new system for calculating subscriptions, the CERN subscription can rise so significantly in member states' own currencies because of exchange rate fluctuations.**[147] Even though the bulk of CERN expenditure is made in

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[141] Ev p157.

[142] Ev p179.

[143] Ev p43.

[144] See *Forward Look of Government-funded Science, Engineering and Technology*, OST 1994, p99, *Forward Look* 1995, p42.

[145] Annex II, plvi.

[146] Ev p179.

[147] Seven twelfths of the increases last two years are attributable to exchange rate fluctuations, Annex II.

Swiss francs,[148] the organisation still benefits if it makes purchases from countries whose currency has depreciated against the Swiss franc. Since it is CERN's policy to place its contracts in a larger number of countries than has been the case in the past, this is increasingly likely to happen. **In view of this all CERN member states may wish to reconsider whether CERN should bear some of the burden of exchange rate fluctuations, and we would support negotiations to this end.**

V. CONCLUSION

94. As the system now stands, PPARC has little control over its own budget. It relies on international facilities to conduct its science, and its programme would be impossible without them. However, this means that although it can influence the programmes and budgets of international organisations it does not have ultimate control. In addition, fluctuations in the CERN and ESA subscriptions which are unrelated to the scientific programmes of those organisations reduce the financial flexibility available both to PPARC and to the entire Science Budget.

95. There is a fundamental imbalance in the United Kingdom between the subscriptions required to gain access to international facilities and the domestic programme needed to support them. The United Kingdom already spends far less on the domestic programmes than France and Germany.[149] These domestic programmes finance the detectors at CERN, or the instruments on space missions, and the scientists who use them, as well as any programmes within the country concerned. Further cuts would jeopardise the international standing of the research community. Moreover, the fact that most projects require long term commitments and cannot be unilaterally altered, means that alterations in the resources available to PPARC will be borne on the domestic budget, and on those parts such as travel grants which are most easily cut, so that sustaining full participation even in those collaborations in which the United Kingdom has been able to take part is increasingly difficult.

96. The pressure has fallen on both communities, but PPARC's plans suggest it will in future fall increasingly on particle physics. We agree with PPARC Council that attempting to share the burden further risks making both the particle physics and astronomy programmes unsustainable. However, we think it would be unfortunate to waste the considerable financial and intellectual investment the United Kingdom has already made in particle physics.

97. The key project in particle physics is the Large Hadron Collider, and it is this which has placed the PPARC budget under such pressure. The CERN Council will finalise the timetable for the LHC in 1997, and accordingly decisions on the instrumentation required will be made in the next two years. The question of the resources which should be allocated to the LHC has exercised Science Ministers for the last three years, as evidenced by the letters printed as Annex V to this Report. **It is essential that the problems facing PPARC are resolved speedily so that the particle physics community knows at what level it can expect to participate in what has been confidently described as the "pre-eminent world centre for particle physics"[150] and is, among other things, a huge investment in United Kingdom scientists.**

98. The decision to proceed with the Large Hadron Collider is the result of an international agreement at inter-governmental level, even though it may have been enthusiastically

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[148] Ev p164.

[149] Ev p65.

[150] Ev p6.

supported by particle physicists. The Government must honour the commitment it so recently made. However, it should not do so in a way which will distort the PPARC programme or the Science Budget.

99. On balance, we agree with the Government; **we consider that placing international subscriptions within the Science Budget means that the science conducted at international organisations is subject to rigorous scrutiny to ensure the money is well spent, while preventing the abandonment of scientifically important programmes on cost grounds. However, it does not seem reasonable that the Science Budget in part or as a whole should bear the considerable costs caused by fluctuations in international subscriptions which have nothing to do with the scale of the scientific programme.**

100. **Accordingly we recommend that the Treasury should bear the cost of any fluctuations in international subscriptions arising from fluctuations in the exchange rate, or increases in the United Kingdom's relative prosperity. As a quid pro quo, any notional gains made from such fluctuations should be returned to the Treasury.**

101. Removing responsibility for fluctuations in international subscriptions from the Science Budget will, in effect, hold the cost of the CERN subscription to PPARC at or below the level which PPARC wishes, but it will not provide enough resources to solve all PPARC's problems. While there is scope for some pressure on CERN and ESA to reduce their costs, over and above the reductions already agreed, we consider that this is unlikely to produce significant savings in the time required. The United Kingdom should also make clear that the drive for efficiency does not prevent it from being an enthusiastic and whole hearted member of such collaborations.

102. **We consider that there is a good case for a general increase in the Science Budget.** Although both the Science Budget and total funding of the Science Base has increased in real terms over the last ten years, that spending has not kept pace with the growth in GDP. Since 1986/87 funding of the Science Base has fallen as a percentage of GDP from 0.34% to 0.30% in 1996/97. If the Science Base had grown in line with GDP it would be some £279 million higher than its current figure. In addition the Science Base has become an increasingly important part of the national research capacity, since total government expenditure on civil R&D has fallen even more quickly, from 0.61% of GDP in 1986 to 0.43% in 1994; a drop of 30%.[151] As a result the United Kingdom would now appear to spend less than all the other G7 countries on civil R&D as a percentage of GDP. In 1992, the last year for which full figures are available, only Japan and the USA, countries with traditional low government expenditure on civil R&D, spent less proportionately than the United Kingdom. By 1994, it would appear that the United Kingdom had fallen behind both these countries.[152]

103. Although Research Council funding has not been as badly affected as university research funding, it has still fallen slightly in relation to the growth in GDP (after excluding the dual support transfer). Even though it is clearly Government policy to reduce the part civil departments play in commissioning R&D,[153] there will always be a need for research to underpin Government policies. It seems likely that as departmental research establishments are reduced in number, Government departments are likely to become even more dependent on Research Councils for scientific research and advice. We believe that Science Base funding should be increased, and the Research Councils should share in this. However, we

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[151] Cm 3257-II, Table 7.8, GDP deflator supplied by Office of National Statistics; GDP forecast for 1996/97 taken from HM Treasury *Financial Statement and Budget Report 1996-97* HC(1995-96)30.

[152] *Ibid*, Table 7.8.

[153] Expenditure has fallen by 42% in real terms over the last ten years.

do not consider that the proportion of the Science Budget devoted to Particle Physics should rise or that PPARC would have an automatic claim to any increase in the Science vote.

104. This still leaves the problem of how to deal with "lumpy" expenditure, which was identified by Lord Phillips before the new research council system was introduced. It is likely that other Research Councils will need major capital facilities in the near future, and the Treasury will have to find a way to accommodate them. The investment needed to realise the scientific benefits of the LHC would be a suitable test of the new systems which may be needed.

105. **We consider that PPARC should receive adequate funding to exploit the Large Hadron Collider.** We would prefer that this funding was given outright, since we do not consider it is advisable to make long term decisions on the as yet unquantifiable results of scientific expenditure. If such a commitment is impossible to make, the Government should treat the expenditure as a loan and reduce the PPARC allocation by an equivalent amount once the period has ended. There are currently no plans for a successor to the LHC and the CERN budget is calculated to fall by up to 20% at the end of the construction period;[154] there is no reason to believe that subscriptions could not fall sharply, if the Government was prepared to resist any plans for a further large machine after the LHC.

106. Such a course, if adopted, is tantamount to declaring that the United Kingdom will, over the long term, significantly reduce its commitment to particle physics. The particle physics community will have to be warned that it is extremely unlikely that funding will be found for such large facilities in future. This may lead to a run down of the subject, but it will at least allow any run down to be planned. It may lead to the discovery of cheaper methods of doing particle physics. It will also mean that should a major new international facility be proposed in future the United Kingdom will have made its position clear sufficiently early to ensure that refusal to participate will be understood by its international partners.

107. The proposals we make above would ensure that the United Kingdom could get a reasonable level of return from its investment in international facilities. If this money is not found, then radical measures will have to be sought. One such might be that, rather than writing off the CERN subscription as a contribution to international science, the Government should seek to open an international debate on the appropriate level of funding for particle physics. The agreement to the LHC has pre-empted a proper debate about the amount of support particle physics should receive. This is not a question for the United Kingdom alone; there are comparable pressures on the science budgets of other major contributors to CERN.

108. The CERN Council and government officials dealing specifically with the CERN programme are not likely to propose any reduction in the CERN budget. The non-member states who are being invited to contribute to CERN are unlikely to volunteer a full part of the costs, even though some have been generous.[155] The USA, whose scientists are expected to be the largest national group at the LHC, is offering sums which "fall short of the Member States' expectations."[156] It has been argued that extension of the timetable for the construction of the LHC would jeopardise contributions from non-member states. However, those contributions would do nothing to reduce the annual costs to Member states and they should not be taken into consideration when the CERN budget is decided. A better solution would be to invite non-European states to become full members of CERN, and if necessary revise the treaty to this end.

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[154] Ev p179.

[155] Annex II, plii.

[156] Ev p167.

109. The United Kingdom should take a lead in discussing these issues with other G7 science ministers, who are increasingly faced with similar problems. It may prove possible to build the political consensus necessary to create an atmosphere in which CERN could become a truly global collaboration or the LHC construction period could be spread over sufficient years to redress the balance between the international and domestic programmes in Britain, and achieve equally necessary re-balancing in other countries. There are pressing needs for new international programmes in other sciences. The SSC has been cancelled in the United States, and it is realistic to suppose that this will have repercussions elsewhere. **The Committee believes the LHC should be completed, but it needs to be completed in such a way as to avoid making excessive peak demands on resources.**

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

We hope that competitive tendering for services formerly provided by the Royal Observatories will lead to significant savings; it is essential that it should not lead to less skilled development and operation of the advanced instrumentation needed to maintain the telescopes at the forefront of astronomy and astrophysics. (Para 17)

The scientific goals of the Cluster satellites were important and the scientific information they were to have gathered should not be lost for lack of funds. (Para 28)

We recommend that the cost of any United Kingdom instrumentation on a mission to replace Cluster, up to the value of the instrumentation lost on the original project, should be borne by the Contingency Fund. (Para 28)

Any positive recommendations about the future funding of PPARC should not be taken to imply a belief that other parts of the Science Budget should be cut to compensate for increases in expenditure on PPARC's budget. (Para 32)

We consider that withdrawal from fundamental research would, in effect, terminate the United Kingdom's claims to be among the most advanced nations of the world. Moreover, it would squander national expertise in one of the areas in which British research leads the world. It would also send a very negative message to young people considering scientific careers. We have no wish to see that happen. (Para 34)

We consider that international collaboration has a value over and above the scientific opportunities it affords. Most importantly, it fosters networks of highly skilled people; it gives British researchers and, potentially, British industry, access to the best research available. (Para 37)

The knowledge that international collaboration to investigate the depths of atomic structure or the further reaches of the universe is not simply possible, but is being triumphantly carried out, should act as a spur to collaborate on other more mundane problems which need international solutions. (Para 37)

We consider that it is important that those at the highest level should be seen to take a close and continuing interest in CERN and ESA, even if they are not best placed to deal directly with all the business conducted there. It is unfortunate that the Chief Executive's visits to these international organisations have largely taken place when budgets were being negotiated or when bad news had to be delivered. (Para 57)

We welcome the Government's initiative in putting forward a coherent long term strategy for Britain's space activities. We support its proposals for ensuring that both national policy, and collaboration with ESA, are designed to strengthen industry and make it internationally competitive. We hope this will lead to benefits for the overall space programme as the private sector increasingly becomes able and willing to provide some of the finance for its activities. We trust the new policy on space will ensure that in future the United Kingdom will participate in technology development programmes at an appropriate level. (Para 61)

We consider it would be appropriate for the DTI to provide at least some of the funding necessary for industrial liaison, since it is the department charged with promoting technology transfer. (Para 65)

We hope that the compilers of the Forward Look and its Statistical Supplement will bear in mind that one of the functions of such publications is to allow comparisons to be made over time, and will accordingly ensure that in future statistics are comparable from one year to the next. (Para 68)

Like our colleagues in the Lords who examined this problem in 1991, we believe that it is inappropriate for the Science Budget to bear the costs of fluctuations in international subscriptions. (Para 82)

We are concerned that the United Kingdom is now proposing to renegotiate an international agreement on grounds which should have been apparent at the time the agreement was first reached. Nonetheless, it is also a cause for concern that even under the new system for calculating subscriptions, the CERN subscription can rise so significantly in member states' own currencies because of exchange rate fluctuations. (Para 93)

In view of this all CERN member states may wish to reconsider whether CERN should bear some of the burden of exchange rate fluctuations, and we would support negotiations to this end. (Para 93)

It is essential that the problems facing PPARC are resolved speedily so that the particle physics community knows at what level it can expect to participate in what has been confidently described as the "pre-eminent world centre for particle physics" and is, among other things, a huge investment in United Kingdom scientists. (Para 97)

We consider that placing international subscriptions within the Science Budget means that the science conducted at international organisations is subject to rigorous scrutiny to ensure the money is well spent, while preventing the abandonment of scientifically important programmes on cost grounds. However, it does not seem reasonable that the Science Budget in part or as a whole should bear the considerable costs caused by fluctuations in international subscriptions which have nothing to do with the scale of the scientific programme. (Para 99)

Accordingly we recommend that the Treasury should bear the cost of any fluctuations in international subscriptions arising from fluctuations in the exchange rate, or increases in the United Kingdom's relative prosperity. As a quid pro quo, any notional gains made from such fluctuations should be returned to the Treasury. (Para 100)

We consider that there is good case for a general increase in the Science Budget. (Para 102)

We consider that PPARC should receive adequate funding to exploit the Large Hadron Collider. (Para 105)

The Committee believes the LHC should be completed, but it needs to be completed in such a way as to avoid making excessive peak demands on resources. (Para 109)

LIST OF TERMS AND ABBREVIATIONS

BNSC	-	British National Space Centre
CCLRC	-	Council for the Central Laboratory of the Research Councils
CERN	-	European Organisation for Nuclear Research
DESY	-	Deutches Elektronen Synchrotron Laboratory
EISCAT	-	European Incoherent Scatter Facility
EPSRC	-	Engineering and Physical Sciences Research Council
ESA	-	European Space Agency
ESO	-	European Southern Observatory
FIRST	-	Far InfraRed and Submillimetric Space Telescope
HERA	-	Hadron Elektron Ring Anlage
ILL	-	Institut Laue Langevin
INTEGRAL	-	International Gamma Ray Observatory
LEP	-	Large Electron Positron Collider
LHC	-	Large Hadron Collider
NASA	-	National Aeronautics and Space Administration (USA)
NERC	-	Natural Environment Research Council
OST	-	Office of Science and Technology
PIPSS	-	PPARC Industrial Programme Support Scheme
POST	-	Parliamentary Office of Science and Technology
PPARC	-	Particle Physics and Astronomy Research Council
ROPA	-	Realising Our Potential Awards
SERC	-	Science and Engineering Research Council
SOHO	-	Solar and Heliospheric Observatory
SSC	-	Superconducting Super Collider
WIMPS	-	Weakly Interacting Massive Particles
XMM	-	X-ray Multi Mirror Mission

ANNEX I

Table 1-1: Trend in the PPARC's R&D Expenditure - £million (1975/76 to 1985/86)

Based on previously unpublished 'Research Budget' data provided by PPARC (see footnote 1).

(a) £ million, cash terms (Current Prices)	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86
Total PPARC R&D Expenditure:											
Particle Physics {2}	33.9	37.0	37.0	40.3	38.7	35.4	36.2	41.9	51.6	55.6	58.2
Astronomy and Planetary Science {3}	24.3	26.3	27.5	28.2	30.1	33.7	36.9	38.8	40.9	46.5	49.1
Total PPARC R&D Expenditure	**58.2**	**63.3**	**64.5**	**68.5**	**68.8**	**69.1**	**73.1**	**80.7**	**92.4**	**102.1**	**107.3**
Domestic:											
Particle Physics {4}	15.3	13.8	13.2	12.6	13.4	12.9	13.7	15.3	19.2	19.9	20.0
Astronomy and Planetary Science {4}	17.3	18.5	16.5	18.4	21.1	24.3	27.3	29.1	29.2	33.6	33.3
Total Domestic Expenditure	32.6	32.3	29.7	31.0	34.5	37.2	41.0	44.4	48.5	53.5	53.3
International:											
CERN {4}	18.6	23.2	23.8	27.7	25.3	22.4	22.5	26.6	32.4	35.7	38.2
ESA {4}	7.0	7.8	11.0	9.8	9.0	9.4	9.6	9.7	11.6	12.9	15.8
Total International Expenditure	25.6	31.0	34.8	37.5	34.3	31.8	32.1	36.3	44.0	48.7	54.0
Total PPARC Expenditure	**58.2**	**63.3**	**64.5**	**68.5**	**68.8**	**69.1**	**73.1**	**80.7**	**92.4**	**102.1**	**107.3**
Science Vote											
Science Vote {1}	171	216	249	266	322	383	447	478	514	546	579
Science Vote (excluding Dual Support) {1}	171	216	249	266	322	383	447	478	514	546	579

(b) £ million, real terms (Constant 1995/96 Prices)	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86
Total PPARC R&D Expenditure:											
Particle Physics {2}	145.7	140.4	123.5	120.7	99.3	76.8	71.6	77.4	91.0	93.5	92.7
Astronomy and Planetary Science {3}	104.4	99.7	91.7	84.5	77.3	73.2	73.1	71.7	72.1	78.2	78.2
Total PPARC R&D Expenditure {1}	**250.1**	**240.1**	**215.2**	**205.2**	**176.6**	**150.0**	**144.7**	**149.1**	**163.1**	**171.7**	**170.9**
Domestic:											
Particle Physics {1}	65.7	52.4	44.1	37.7	34.3	28.1	27.1	28.2	33.9	33.4	31.9
Astronomy and Planetary Science {1}	74.4	70.1	55.0	55.1	54.2	52.8	54.1	53.8	51.6	56.5	53.0
Total Domestic Expenditure	140.1	122.5	99.1	92.8	88.5	80.9	81.2	82.0	85.5	89.9	84.9
International:											
CERN {1}	80.0	88.0	79.4	83.0	65.0	48.7	44.5	49.2	57.1	60.1	60.8
ESA {1}	30.0	29.6	36.7	29.4	23.1	20.4	19.0	17.9	20.5	21.7	25.2
Total International Expenditure	110.0	117.6	116.1	112.4	88.1	69.1	63.5	67.1	77.6	81.8	86.0
Total PPARC Expenditure {1}	**250.1**	**240.1**	**215.2**	**205.2**	**176.6**	**150.0**	**144.7**	**149.1**	**163.1**	**171.7**	**170.9**
Science Vote:											
Science Vote {1}	735	819	831	797	827	832	885	883	907	918	922
Science Vote (excluding Dual Support) {1}	735	819	831	797	827	832	885	883	907	918	922

{1} Original Data Provided by PPARC

The re-organisation of the Research Councils in 1994/95, which transferred the responsibility for Particle Physics and Astronomy & Planetary Science from SERC to PPARC, coincided with a change in categorisation of the activities that make up Particle Physics and Astronomy & Planetary Science, ie. the categories used by PPARC are not the same as those used SERC. As a result it is not possible to use the historical data in the 'Forward Look' and 'Annual Review of Government Funded R&D' to identify trends in funding of these areas of UK R&D However, PPARC were able to supply the Committee with 'Research Budget' data which PPARC use for internal planning purposes. This data is not the same as that recorded in the 'Forward Look' In particular it excludes: (a) an amount, estimated by PPARC, for dual support transfer in order to maintain a consistent time series, (b) administration and programme support; (c) studenships. (d) fellowships

{2} Total PPARC Particle Physics R&D Expenditure assumed = (Domestic Particle Physics) + (CERN Subscriptions)

{3} Total PPARC Astronomy & Planetary Science R&D Expenditure assumed = (Domestic Astronomy & Planetary Science) + (ESA Subscriptions)

{4} Spending in cash terms calculated from original PPARC data using the implied GDP deflator (obtained from Science Vote data provided by PPARC)

Table 1-2: Trend in the PPARC's R&D Expenditure - £million (1985/86 to 1995/96)

Based on previously unpublished 'Research Budget' data provided by PPARC (see footnote 1).

(a) £ million, cash terms (Current Prices)	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96
Total PPARC R&D Expenditure:											
Particle Physics {2}	58.2	61.7	75.0	73.5	67.9	71.5	76.4	75.3	79.2	76.1	87.2
Astronomy and Planetary Science {3}	49.1	47.8	53.6	60.5	66.9	65.2	66.8	72.1	74.8	80.1	83.3
Total PPARC R&D Expenditure	**107.3**	**109.6**	**128.6**	**134.1**	**134.8**	**136.6**	**143.2**	**147.4**	**154.0**	**156.2**	**170.5**
Domestic:											
Particle Physics {4}	20.0	16.7	18.6	19.0	18.9	18.5	18.2	19.8	21.3	20.3	20.7
Astronomy and Planetary Science {4}	33.3	30.6	32.0	34.4	38.2	38.8	40.5	39.4	40.7	42.5	44.8
Total Domestic Expenditure	53.3	47.3	50.6	53.4	57.2	57.3	58.7	59.2	62.0	62.9	65.5
International:											
CERN {4}	38.2	45.1	56.4	54.6	49.0	53.0	58.2	55.5	57.9	55.8	66.5
ESA {4}	15.8	17.2	21.5	26.1	28.7	26.4	26.3	32.7	34.0	37.6	38.5
Total International Expenditure	54.0	62.3	78.0	80.7	77.6	79.4	84.5	88.2	92.0	93.3	105.0
Total PPARC Expenditure	**107.3**	**109.6**	**128.6**	**134.1**	**134.8**	**136.6**	**143.2**	**147.4**	**154.0**	**156.2**	**170.5**
Science Vote											
Science Vote {1}	579.0	607.0	657.0	699.0	824.0	897.0	921.0	1013.0	1165.0	1236.0	1282.0
Science Vote (excluding Dual Support) {1}	579.0	607.0	657.0	699.0	824.0	897.0	921.0	1005.0	1040.0	1082.0	1128.0

(b) £ million, real terms (Constant 1995/96 Prices)	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96
Total PPARC R&D Expenditure:											
Particle Physics {2}	92.7	95.5	110.1	101.1	87.2	85.1	85.7	81.1	82.9	78.2	87.2
Astronomy and Planetary Science {3}	78.2	74.0	78.6	83.2	85.9	77.6	74.9	77.6	78.2	82.3	83.3
Total PPARC R&D Expenditure {1}	**170.9**	**169.5**	**188.7**	**184.3**	**173.1**	**162.7**	**160.6**	**158.7**	**161.1**	**160.5**	**170.5**
Domestic:											
Particle Physics {1}	31.9	25.8	27.3	26.1	24.3	22.0	20.4	21.3	22.3	20.9	20.7
Astronomy and Planetary Science {1}	53.0	47.4	47.0	47.3	49.1	46.2	45.4	42.4	42.6	43.7	44.8
Total Domestic Expenditure	84.9	73.2	74.3	73.4	73.4	68.2	65.8	63.7	64.9	64.6	65.5
International:											
CERN {1}	60.8	69.7	82.8	75.0	62.9	63.1	65.3	59.8	60.6	57.3	66.4
ESA {1}	25.2	26.6	31.6	35.9	36.8	31.4	29.5	35.2	35.6	38.6	38.5
Total International Expenditure	86.0	96.3	114.4	110.9	99.7	94.5	94.8	95.0	96.2	95.9	104.9
Total PPARC Expenditure {1}	**170.9**	**169.5**	**188.7**	**184.3**	**173.1**	**162.7**	**160.6**	**158.7**	**161.1**	**160.5**	**170.4**
Science Vote:											
Science Vote {1}	922.0	939.0	964.0	961.0	1058.0	1068.0	1033.0	1090.6	1218.8	1270.3	1282.0
Science Vote (excluding Dual Support) {1}	922.0	939.0	964.0	961.0	1058.0	1068.0	1033.0	1082.0	1088.0	1112.0	1128.0

{1} Original Data Provided by PPARC

The re-organisation of the Research Councils in 1994/95, which transferred the responsibility for Particle Physics and Astronomy & Planetary Science from SERC to PPARC, coincided with a change in categorisation of the activities that make up Particle Physics and Astronomy & Planetary Science, ie the categories used by PPARC are not the same as those used SERC. As a result it is not possible to use the historical data in the 'Forward Look' and 'Annual Review of Government Funded R&D' to identify trends in funding of these areas of UK R&D However, PPARC were able to supply the Committee with 'Research Budget' data which PPARC use for internal planning purposes. This data is not the same as that recorded in the 'Forward Look' In particular it excludes: (a) an amount, estimated by PPARC, for dual support transfer in order to maintain a consistent time series; (b) administration and programme support, (c) studentships, (d) fellowships

{2} Total PPARC Particle Physics R&D Expenditure assumed = (Domestic Particle Physics) + (CERN Subscriptions)

{3} Total PPARC Astronomy & Planetary Science R&D Expenditure assumed = (Domestic Astronomy & Planetary Science) + (ESA Subscriptions)

{4} Spending in cash terms calculated from original PPARC data using the implied GDP deflator (obtained from Science Vote data provided by PPARC)

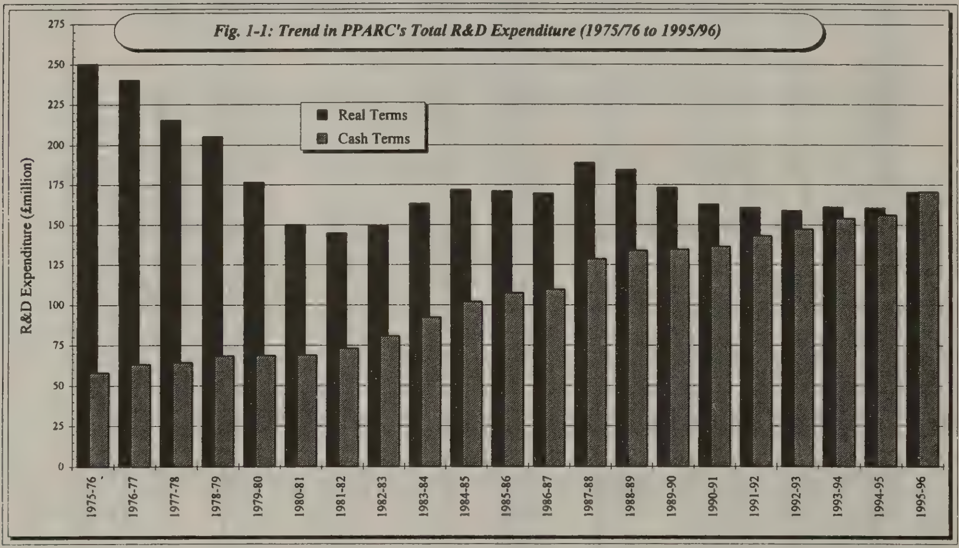

Fig. 1-1: Trend in PPARC's Total R&D Expenditure (1975/76 to 1995/96)

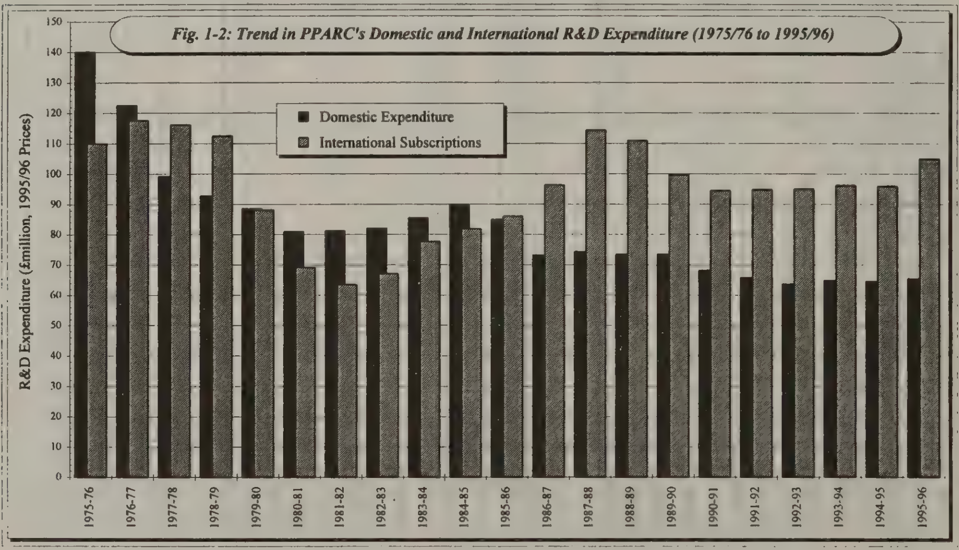

Fig. 1-2: Trend in PPARC's Domestic and International R&D Expenditure (1975/76 to 1995/96)

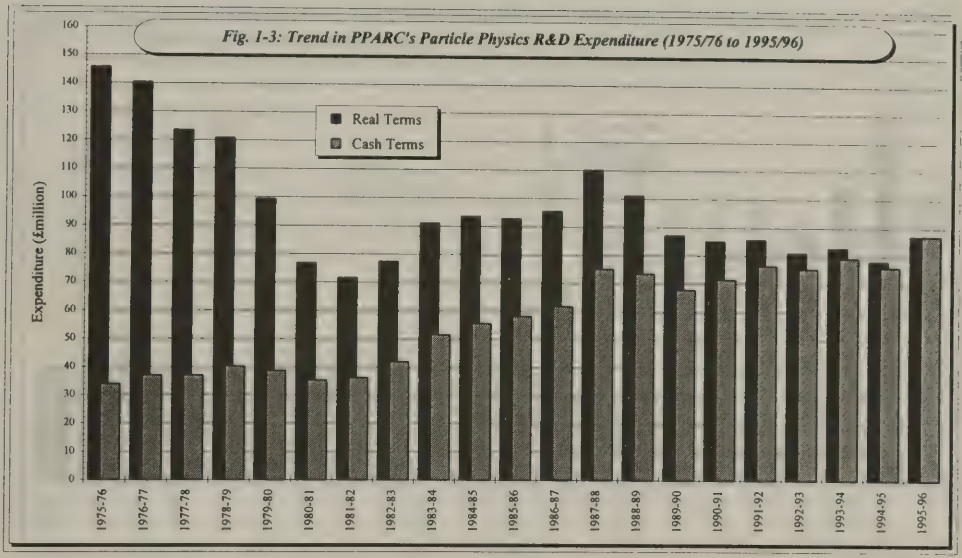
Fig. 1-3: Trend in PPARC's Particle Physics R&D Expenditure (1975/76 to 1995/96)
Real Terms
Cash Terms
Expenditure (£million)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
1975-76
1976-77
1977-78
1978-79
1979-80
1980-81
1981-82
1982-83
1983-84
1984-85
1985-86
1986-87
1987-88
1988-89
1989-90
1990-91
1991-92
1992-93
1993-94
1994-95
1995-96

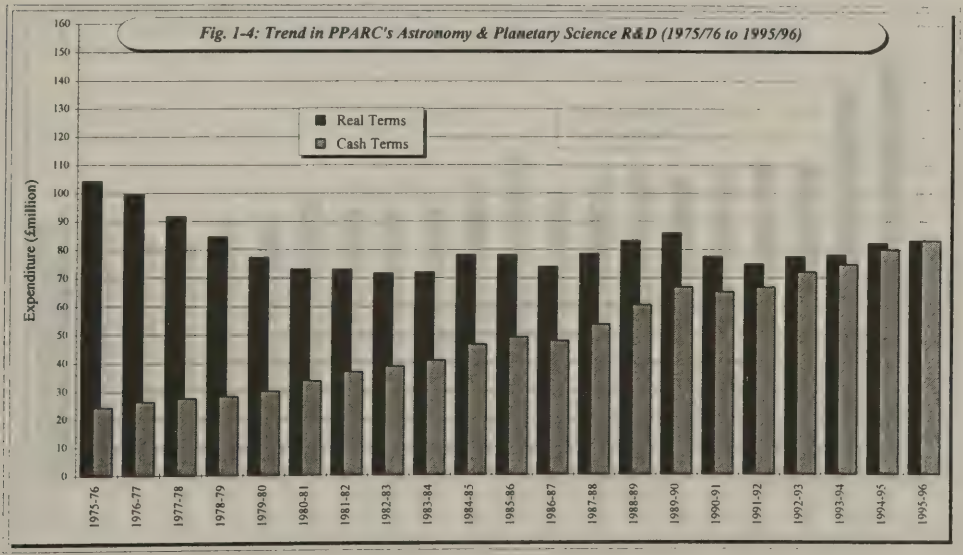
Fig. 1-4: Trend in PPARC's Astronomy & Planetary Science R&D (1975/76 to 1995/96)
Real Terms
Cash Terms
Expenditure (£million)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
1975-76
1976-77
1977-78
1978-79
1979-80
1980-81
1981-82
1982-83
1983-84
1984-85
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1991-92
1992-93
1993-94
1994-95
1995-96

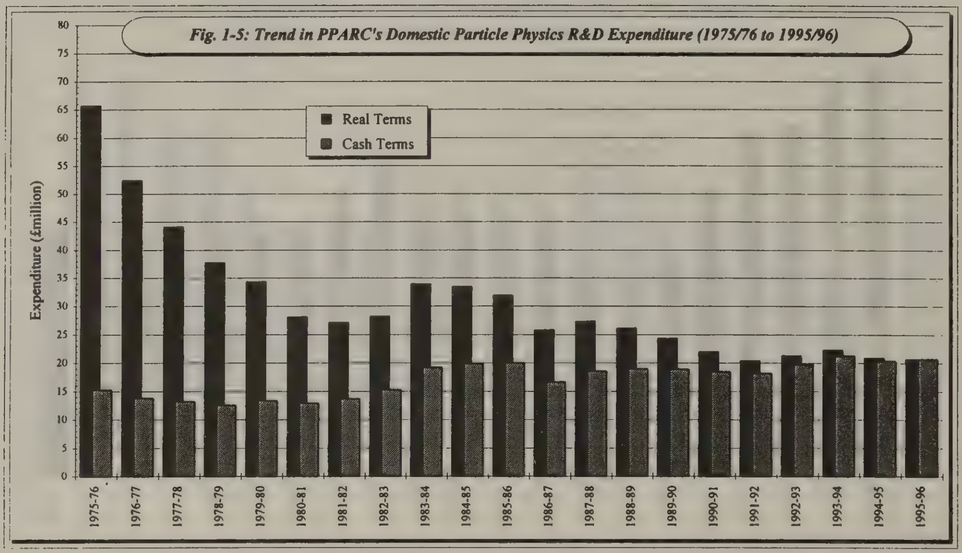

Fig. 1-5: Trend in PPARC's Domestic Particle Physics R&D Expenditure (1975/76 to 1995/96)

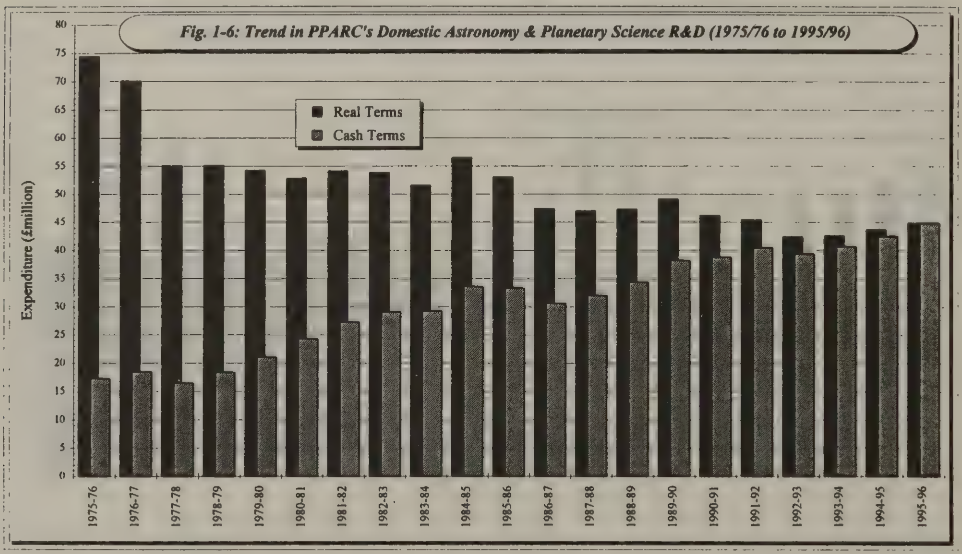

Fig. 1-6: Trend in PPARC's Domestic Astronomy & Planetary Science R&D (1975/76 to 1995/96)

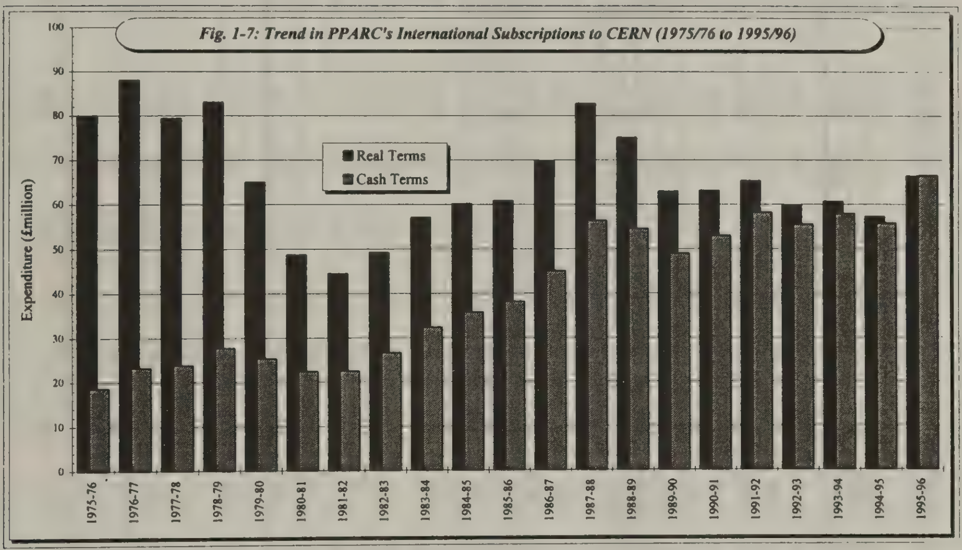

Fig. 1-7: Trend in PPARC's International Subscriptions to CERN (1975/76 to 1995/96)

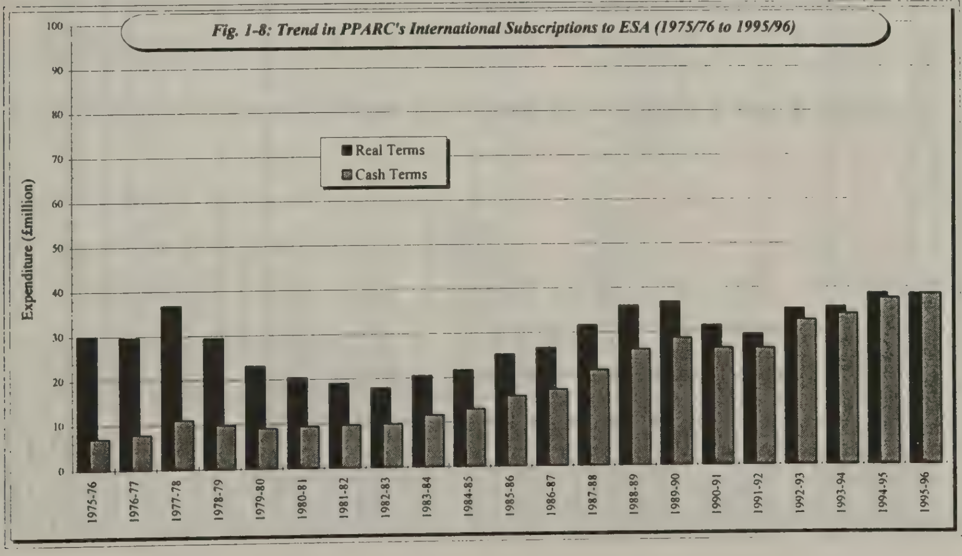

Fig. 1-8: Trend in PPARC's International Subscriptions to ESA (1975/76 to 1995/96)

Table 2-1: Trend in the PPARC's R&D Expenditure (1985/86 to 1995/96)

Based on previously unpublished 'Research Budget' data provided by PPARC (see footnotes to Table 1).

(a) £ million, cash terms (Current Prices)	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96
Total PPARC R&D Expenditure:											
Particle Physics {2}	58.2	61.7	75.0	73.5	67.9	71.5	76.4	75.3	79.2	76.1	87.2
Astronomy and Planetary Science {3}	49.1	47.8	53.6	60.5	66.9	65.2	66.8	72.1	74.8	80.1	83.3
Total PPARC R&D Expenditure	**107.3**	**109.6**	**128.6**	**134.1**	**134.8**	**136.6**	**143.2**	**147.4**	**154.0**	**156.2**	**170.5**
Domestic R&D Expenditure:											
Particle Physics {4}	20.0	16.7	18.6	19.0	18.9	18.5	18.2	19.8	21.3	20.3	20.7
Astronomy and Planetary Science {4}	33.3	30.6	32.0	34.4	38.2	38.8	40.5	39.4	40.7	42.5	44.8
Total Domestic R&D Expenditure	**53.3**	**47.3**	**50.6**	**53.4**	**57.2**	**57.3**	**58.7**	**59.2**	**62.0**	**62.9**	**65.5**
International Subscriptions:											
CERN {4}	38.2	45.1	56.4	54.6	49.0	53.0	58.2	55.5	57.9	55.8	66.5
ESA {4}	15.8	17.2	21.5	26.1	28.7	26.4	26.3	32.7	34.0	37.6	38.5
Total International Subscriptions	**54.0**	**62.3**	**78.0**	**80.7**	**77.6**	**79.4**	**84.5**	**88.2**	**92.0**	**93.3**	**105.0**
Total PPARC R&D Expenditure	**107.3**	**109.6**	**128.6**	**134.1**	**134.8**	**136.6**	**143.2**	**147.4**	**154.0**	**156.2**	**170.5**

(b) £ million, real terms (Constant 1995/96 Prices)	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96
Total PPARC R&D Expenditure:											
Particle Physics {2}	**92.7**	**95.5**	**110.1**	**101.1**	**87.2**	**85.1**	**85.7**	**81.1**	**82.9**	**78.2**	**87.2**
Percentage Change on Previous Year	-0.9	3.0	15.3	-8.2	-13.7	-2.4	0.7	-5.4	2.2	-5.7	11.5
Percentage Change on 1985/86	0.0	3.0	15.3	-8.2	-13.7	-2.4	0.7	-5.4	2.2	-5.7	11.5
Astronomy and Planetary Science {3}	**78.2**	**74.0**	**78.6**	**83.2**	**85.9**	**77.6**	**74.9**	**77.6**	**78.2**	**82.3**	**83.3**
Percentage Change on Previous Year	0.0	-5.4	6.2	5.9	3.2	-9.7	-3.5	3.6	0.8	5.2	1.2
Percentage Change on 1985/86	0.0	-5.4	6.2	5.9	3.2	-9.7	-3.5	3.6	0.8	5.2	1.2
Domestic R&D Expenditure:											
Particle Physics {1}	**31.9**	**25.8**	**27.3**	**26.1**	**24.3**	**22.0**	**20.4**	**21.3**	**22.3**	**20.9**	**20.7**
Percentage Change on Previous Year	-4.5	-19.1	5.8	-4.4	-6.9	-9.5	-7.3	4.4	4.7	-6.3	-1.0
Percentage Change on 1985/86	0.0	-19.1	-14.4	-18.2	-23.8	-31.0	-36.1	-33.2	-30.1	-34.5	-35.1
Astronomy and Planetary Science {1}	**53.0**	**47.4**	**47.0**	**47.3**	**49.1**	**46.2**	**45.4**	**42.4**	**42.6**	**43.7**	**44.8**
Percentage Change on Previous Year	-6.2	-10.6	-0.8	0.6	3.8	-5.9	-1.7	-6.6	0.5	2.6	2.5
Percentage Change on 1985/86	0.0	-10.6	-11.3	-10.8	-7.4	-12.8	-14.3	-20.0	-19.6	-17.5	-15.5
Total Domestic R&D Expenditure	**84.9**	**73.2**	**74.3**	**73.4**	**73.4**	**68.2**	**65.8**	**63.7**	**64.9**	**64.6**	**65.5**
Percentage Change on Previous Year	-5.6	-13.8	1.5	-1.2	0.0	-7.1	-3.5	-3.2	1.9	-0.5	1.4
Percentage Change on 1985/86	0.0	-13.8	-12.5	-13.5	-13.5	-19.7	-22.5	-25.0	-23.6	-23.9	-22.9
International Subscriptions:											
CERN {1}	**60.8**	**69.7**	**82.8**	**75.0**	**62.9**	**63.1**	**65.3**	**59.8**	**60.6**	**57.3**	**66.4**
Percentage Change on Previous Year	1.2	14.6	18.8	-9.4	-16.1	0.3	3.5	-8.4	1.3	-5.4	15.9
Percentage Change on 1985/86	0.0	14.6	36.2	23.4	3.5	3.8	7.4	-1.6	-0.3	-5.8	9.2
ESA {1}	**25.2**	**26.6**	**31.6**	**35.9**	**36.8**	**31.4**	**29.5**	**35.2**	**35.6**	**38.6**	**38.5**
Percentage Change on Previous Year	16.1	5.6	18.8	13.6	2.5	-14.7	-6.1	19.3	1.1	8.4	-0.3
Percentage Change on 1985/86	0.0	5.6	25.4	42.5	46.0	24.6	17.1	39.7	41.3	53.2	52.8
Total International Subscriptions	**86.0**	**96.3**	**114.4**	**110.9**	**99.7**	**94.5**	**94.8**	**95.0**	**96.2**	**95.9**	**104.9**
Percentage Change on Previous Year	5.1	12.0	18.8	-3.1	-10.1	-5.2	0.3	0.2	1.3	-0.3	9.4
Percentage Change on 1985/86	0.0	12.0	33.0	29.0	15.9	9.9	10.2	10.5	11.9	11.5	22.0
Total PPARC R&D Expenditure {1}	**170.9**	**169.5**	**188.7**	**184.3**	**173.1**	**162.7**	**160.6**	**158.7**	**161.1**	**160.5**	**170.4**
Percentage Change on Previous Year	-0.5	-0.8	11.3	-2.3	-6.1	-6.0	-1.3	-1.2	1.5	-0.4	6.2
Percentage Change on 1985/86	0.0	-0.8	10.4	7.8	1.3	-4.8	-6.0	-7.1	-5.7	-6.1	-0.3

{1} to {4}: see footnotes to Table 1.

Table 2-2: Trend in the PPARC's R&D Expenditure, Science Vote and GDP (1985/86 to 1995/96)

Based on previously unpublished 'Research Budget' data provided by PPARC (see footnotes to Table 1).

(d) PPARC R&D as a percentage of Science Vote	**1985-86**	**1986-87**	**1987-88**	**1988-89**	**1989-90**	**1990-91**	**1991-92**	**1992-93**	**1993-94**	**1994-95**	**1995-96**
Science Vote, excluding Dual Support (£ million, Current Prices) {1}	579.0	607.0	657.0	699.0	824.0	897.0	921.0	1005.0	1040.0	1082.0	1128.0
Science Vote, excluding Dual Support (£ million, Constant 1995 Prices	922.0	939.0	964.0	961.0	1058.0	1068.0	1033.0	1082.0	1088.0	1112.0	1128.0
Science Vote Percentage Change on 1985/86 (1995 Prices)	0.0	1.8	4.6	4.2	14.8	15.8	12.0	17.4	18.0	20.6	22.3
Science Vote Percentage Change on Previous Year (1995 Prices)	0.4	1.8	2.6	-0.3	9.2	0.9	-3.4	4.5	0.6	2.2	1.4
PPARC R&D Expenditure as a % Science Vote											
Particle Physics as a % Science Vote	10.1	10.2	11.4	10.5	8.2	8.0	8.3	7.5	7.6	7.0	7.7
Astronomy and Planetary Science as a % Science Vote	8.5	7.9	8.2	8.7	8.1	7.3	7.3	7.2	7.2	7.4	7.4
Total PPARC R&D Expenditure as a % Science Vote	18.5	18.1	19.6	19.2	16.4	15.2	15.5	14.7	14.8	14.4	15.1
Domestic R&D Expenditure:											
Particle Physics as a % Science Vote	3.5	2.7	2.8	2.7	2.3	2.1	2.0	2.0	2.0	1.9	1.8
Astronomy and Planetary Science as a % Science Vote	5.7	5.0	4.9	4.9	4.6	4.3	4.4	3.9	3.9	3.9	4.0
Total Domestic R&D Expenditure as a % Science Vote	9.2	7.8	7.7	7.6	6.9	6.4	6.4	5.9	6.0	5.8	5.8
International Subscriptions:											
CERN as a % Science Vote	6.6	7.4	8.6	7.8	5.9	5.9	6.3	5.5	5.6	5.2	5.9
ESA as a % Science Vote	2.7	2.8	3.3	3.7	3.5	2.9	2.9	3.3	3.3	3.5	3.4
Total International Subscriptions as a % Science Vote	9.3	10.3	11.9	11.5	9.4	8.8	9.2	8.8	8.8	8.6	9.3
Total PPARC R&D Expenditure as a % Science Vote	18.5	18.1	19.6	19.2	16.4	15.2	15.5	14.7	14.8	14.4	15.1

(e) PPARC R&D as a percentage of GDP	**1985-86**	**1986-87**	**1987-88**	**1988-89**	**1989-90**	**1990-91**	**1991-92**	**1992-93**	**1993-94**	**1994-95**	**1995-96**
GDP (£'000 million, Current Prices) {5}	356.2	383.6	421.9	469.8	514.2	549.4	573.6	595.2	628.4	666.1	703.2
GDP (£'000 million, Constant 1995 Prices) {5}	567.6	593.4	647.4	646.7	661.6	654.4	643.1	641.2	657.8	684.4	703.2
GDP Percentage Change on 1985/86 (Constant 1995 Prices)	0.0	4.5	14.1	13.9	16.6	15.3	13.3	13.0	15.9	20.6	23.9
GDP Percentage Change on Previous Year (Constant 1995 Prices)	-0.3	4.5	9.1	-0.1	2.3	-1.1	-1.7	-0.3	2.6	4.0	2.8
PPARC R&D Expenditure as a % GDP											
Particle Physics as a % GDP	0.0163	0.0161	0.0178	0.0157	0.0132	0.0130	0.0133	0.0127	0.0126	0.0114	0.0124
Astronomy and Planetary Science as a % GDP	0.0138	0.0125	0.0127	0.0129	0.0130	0.0119	0.0116	0.0121	0.0119	0.0120	0.0118
Total PPARC R&D Expenditure as a % GDP	0.0301	0.0286	0.0305	0.0285	0.0262	0.0249	0.0250	0.0248	0.0245	0.0234	0.0242
Domestic R&D Expenditure:											
Particle Physics as a % GDP	0.0056	0.0043	0.0044	0.0040	0.0037	0.0034	0.0032	0.0033	0.0034	0.0031	0.0029
Astronomy and Planetary Science as a % GDP	0.0093	0.0080	0.0076	0.0073	0.0074	0.0071	0.0071	0.0066	0.0065	0.0064	0.0064
Total Domestic R&D Expenditure as a % GDP	0.0150	0.0123	0.0120	0.0114	0.0111	0.0104	0.0102	0.0099	0.0099	0.0094	0.0093
International Subscriptions:											
CERN as a % GDP	0.0107	0.0117	0.0134	0.0116	0.0095	0.0096	0.0101	0.0093	0.0092	0.0084	0.0095
ESA as a % GDP	0.0044	0.0045	0.0051	0.0056	0.0056	0.0048	0.0046	0.0055	0.0054	0.0056	0.0055
Total International Subscriptions as a % GDP	0.0152	0.0162	0.0185	0.0172	0.0151	0.0144	0.0147	0.0148	0.0146	0.0140	0.0149
Total PPARC R&D Expenditure as a % GDP	0.0301	0.0286	0.0305	0.0285	0.0262	0.0249	0.0250	0.0248	0.0245	0.0234	0.0242

{1} to {4} see footnotes to Table 1

{5} data for GDP and GDP deflators provided by Office for National Statistics

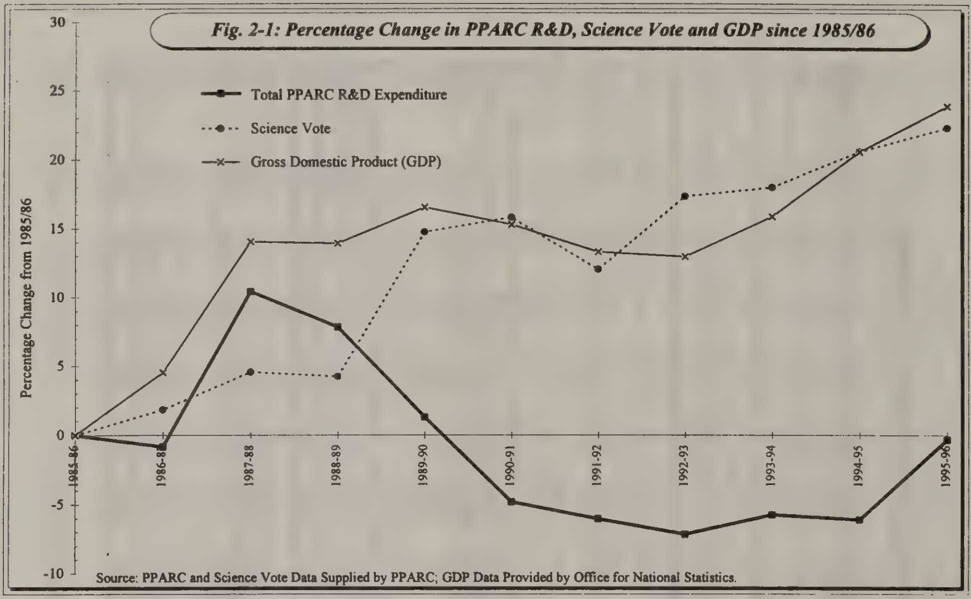

Fig. 2-1: Percentage Change in PPARC R&D, Science Vote and GDP since 1985/86

Source: PPARC and Science Vote Data Supplied by PPARC; GDP Data Provided by Office for National Statistics.

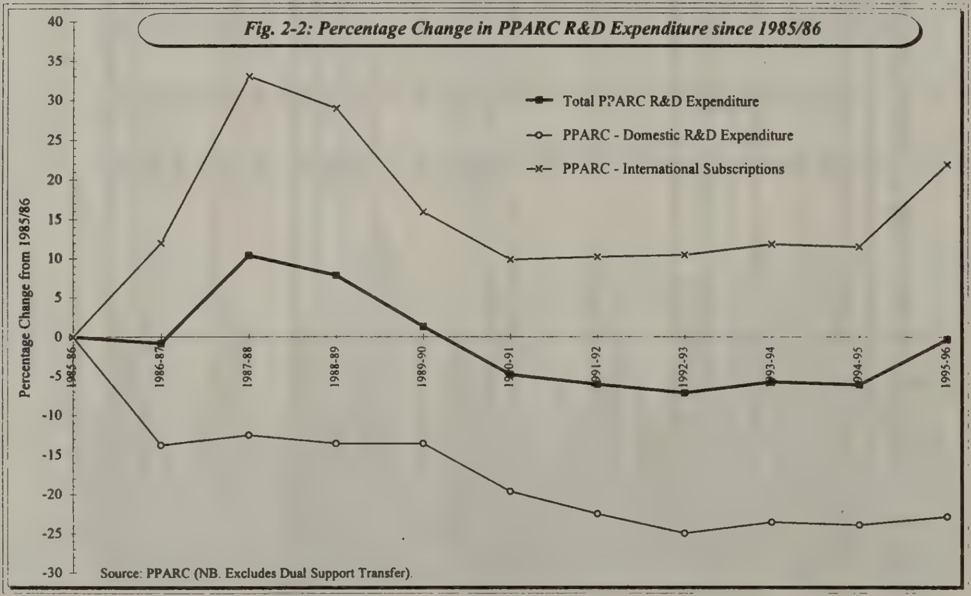

Fig. 2-2: Percentage Change in PPARC R&D Expenditure since 1985/86

Source: PPARC (NB. Excludes Dual Support Transfer).

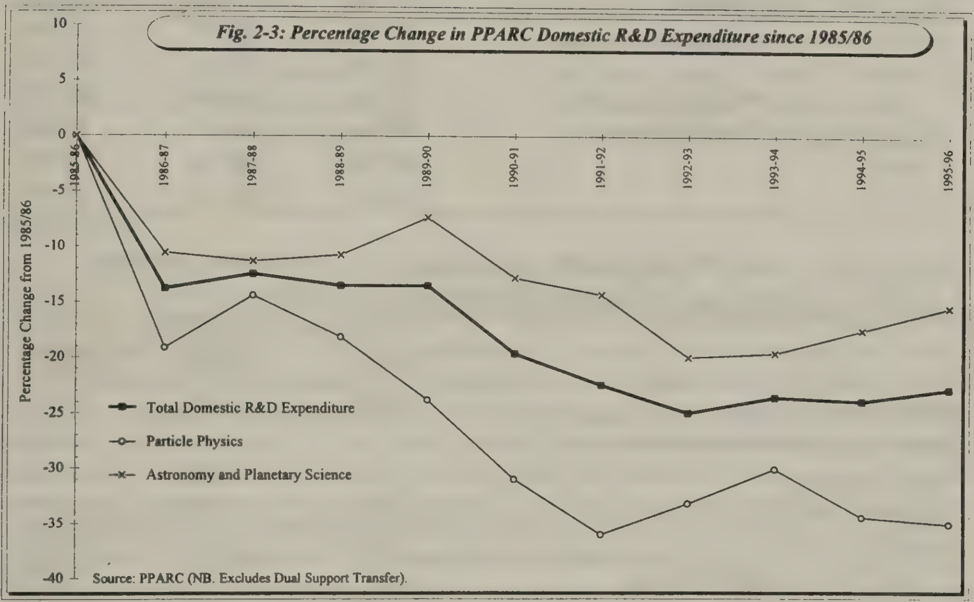

Fig. 2-3: Percentage Change in PPARC Domestic R&D Expenditure since 1985/86

Source: PPARC (NB. Excludes Dual Support Transfer).

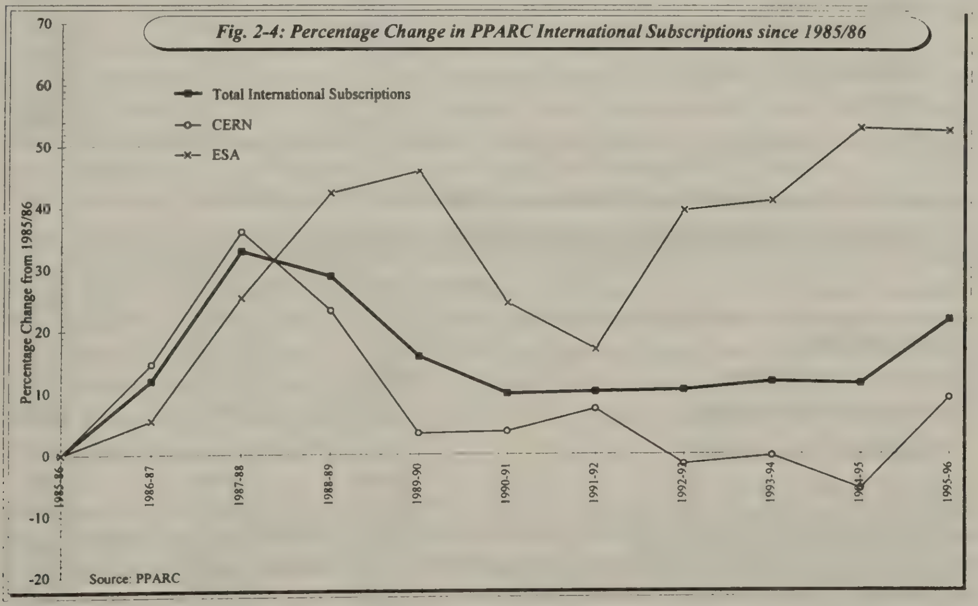

Fig. 2-4: Percentage Change in PPARC International Subscriptions since 1985/86

Source: PPARC

Table 3-1: Trend in PPARC R&D Spending (1985/86 to 1995/96)

Based on previously unpublished data provided by PPARC (see footnotes to Table 1).

	Constant 1995/96 Prices		
	1985/86	1995/96	% Change
Total PPARC R&D Spending	£170.9m	£170.4m	-0.3%
Total Domestic R&D Spending	£84.9m	£65.5m	-22.9%
Particle Physics	£31.9m	£20.7m	-35.1%
Astronomy and Planetary Science	£53.0m	£44.8m	-15.5%
Total International Subscriptions	£86.0m	£104.9m	22.0%
CERN	£60.8m	£66.5m	9.4%
ESA	£25.2m	£38.5m	52.8%

Table 3-2: Trend in PPARC R&D and Science Vote (1985/86 to 1995/96)

Based on previously unpublished data provided by PPARC (see footnotes to Table 1).

	Constant 1995/96 Prices		
	1985/86	1995/96	% Change
Science Vote (£ million)	£922m	£1128m	22.3%
PPARC R&D as a % Science Vote			
Particle Physics	10.1%	7.7%	-23.2%
Astronomy and Planetary Science	8.5%	7.4%	-12.9%
Total PPARC R&D	18.5%	15.1%	-18.5%
Total Domestic R&D Spending	9.2%	5.8%	-36.9%
Particle Physics	3.5%	1.8%	-47.0%
Astronomy and Planetary Science	5.7%	4.0%	-30.9%
Total International Subscriptions	9.3%	9.3%	-0.3%
CERN	6.6%	5.9%	-10.7%
ESA	2.7%	3.4%	24.9%

Table 3-3: Trend in PPARC R&D and GDP (1985/86 to 1995/96)

Based on previously unpublished data provided by PPARC (see footnotes to Table 1).

	Constant 1995/96 Prices		
	1985/86	1995/96	% Change
GDP (£billion)	£567.6bn	£703.2bn	23.3%
Science Vote (£ million)	£922m	£1128m	22.3%
Science Vote as a % GDP	0.162%	0.160%	-1.2%
PPARC R&D as a % GDP			
Particle Physics as a % GDP	0.0163	0.0124	-23.9%
Astronomy and Planetary Science as a % GD	0.0138	0.0118	-14.5%
Total PPARC R&D as a % GDP	0.0301	0.0242	-19.6%
Total Domestic R&D Spending as a % GDP	0.0150	0.0093	-38.0%
Particle Physics as a % GDP	0.0056	0.0029	-48.2%
Astronomy and Planetary Science as a % G	0.0093	0.0064	-31.2%
Total International Subscriptions as a %GDP	0.0152	0.0149	-2.0%
CERN as a % GDP	0.0107	0.0094	-12.1%
ESA as a % GDP	0.0044	0.0055	25.0%

ANNEX II

VISIT TO CERN ON MONDAY 22 APRIL 1996

Members present:

The Chairman	Mrs Anne Campbell
Mr Spencer Batiste	Dr Lynne Jones
Dr Jeremy Bray	Sir Trevor Skeet
Mr Ian Bruce	Mr Patrick Thompson

Introduction

Professor Llewellyn Smith, the Director General, welcomed the Committee to CERN. He outlined the current and future experiments. The current machine, LEP, would be fully exploited until the end of the '90s after which the LHC would be built and installed in the first years of the next century, using the resources already available - notably four of the five accelerators already at CERN. This reuse of existing equipment was routine; the LEP tunnel had been designed in such a way that it could house another accelerator after the LEP programme finished, and it would be possible to put LEP back in the tunnel above the LHC, in order to collide electrons (e) with protons (p), at five times the energy of the ep collider HERA, although it was planned to use the LHC alone at first.

The UK and Germany had resisted CERN's request for a level budget in real terms. The budget for the next three years was frozen, and CERN was working on the assumption of 2% inflation but only 1% increase in funds thereafter. On this budget, the LHC would have to be built in two stages; it would operate with two-thirds of its magnets in place before being upgraded a few years later. This would ultimately cost more than building the machine in one step. As Council had agreed, Professor Llewellyn Smith was attempting to encourage non-Member States to contribute funds to enable the machine to be built in one stage.[157] The US was being asked for voluntary contributions - the open door policy of US scientists using European facilities and European scientists using US facilities worked well and the Director General did not want to jeopardise this arrangement by directly linking US funding to the ability of US researchers to participate in the project. The US could contribute "know-how" gained in the development of the now cancelled SSC, as well as finance. Non-Member States would only contribute if their money "added value"; they would see no point in paying for something that CERN Members would do anyway. He expected that funds would be found to enable the LHC to be built in a single stage, although it might not be completed until 2005 rather than 2004.

Staff numbers had peaked at 3,700 in the 1970s; there were currently 2,850; this was going to be lowered to 2,150 by the time the LHC was on line. LEP would close in 1999, unless new discoveries changed this decision. It had been a magnificent success but its life was likely to be shorter than expected because so far at least the "standard model" had not been challenged by its results, which it had brilliantly confirmed. The LHC should have at least a fifteen year lifespan. Four experiments (arrays of detectors) were running on LEP (Professor Llewellyn Smith thought three might have been adequate but the fourth had been provided at little cost to CERN). Each experiment was designed with a different mixture of abilities (and risks). At least two complementary "general-purpose" detectors would be needed for the LHC and two additional specialised detectors were envisaged. The tunnel had four access shafts in addition to the four experimental shafts, so there could be more than four experiments if needed.

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[157] For details see his written evidence, Ev pp160-168.

The OPAL experiment was described by Professor Janet Carter. This had a high level of UK involvement (23% of total staff). LEP 1 had confirmed earlier hints that there are only three neutrinos (this is a fundamental piece of information: the number is not fixed by the standard model); its upgrade, LEP2 (which would be on-stream this summer) would run at higher energy levels and be involved in a search for new phenomena (supersymmetric particles, Higgs boson, ...) and the systematic study of W particles. Data were taken night and day for the six months the machine operated (it was maintained and improved in the other six months).

Tour of Facilities

The Committee visited:

- the OPAL Experiment (Omni-Purpose Apparatus at LEP)
- the LEP Collider
- the LEAR Experiment
- Large Hadron Collider Technologies

Private Meeting with Professor Llewellyn Smith

Professor Llewellyn Smith said that the UK had provided scientific leadership at CERN - for example three of the five major accelerator projects had UK project leaders. When Professor Llewellyn-Smith had arrived as Director General six out of the thirteen Heads of Division had been British; he had reduced this to three (one of whom had dual nationality).

Although the CERN budget had remained constant in Swiss francs, the UK's contribution had increased by over 25% in the previous two years. Some 40% of this increase was attributable to the relatively rapid economic growth of the UK, which had come out of recession earlier than other European countries, while 60% was caused by currency depreciation. A weakening currency increased the cost of buying Swiss francs, but this was partly compensated by a corresponding decrease in national wealth expressed in Swiss francs, and hence in the percentage contribution to CERN. The latter effect increased the percentage payable by countries with strong currencies, which were therefore penalised for the weakness of other currencies (the UK bore the largest responsibility having had the weakest of all CERN Member State currencies in the recent past). The net effect was that (apart from the effects of the lag between calculating and paying contributions) all Member States had suffered exactly the same increase in their contributions as a result of currency changes (except for Germany as its contribution was at a fixed ceiling as a percentage of the budget).

Unfortunately the rise in the Swiss franc had not resulted in a significant increase in CERN's disposable income; 75% of its expenditure, including salaries, was made in Swiss francs. There had been some gains in the other 25% of expenditure, but the budget had still declined in real terms (although less than had been expected) since Swiss inflation had been 2.1% in the previous year.

In summary, it was not possible to protect against the effects of a strong Swiss franc if it rose against the currencies of all Member States. Professor Llewellyn Smith did not believe that the Swiss franc could continue to strengthen he put its recent rise down to German buying of Swiss francs as a haven against the effects of Economic and Monetary Union. CERN had studied the effects of making payments in ECUs, which turned out to be small.

CERN was seen as a partner in European Union research but received little funding from the Fourth Framework programme. The Director General believed it would be inappropriate for the particle physics programme to receive additional funding from the EU but he thought CERN could and should be used much more as a European Union resource able to provide expertise on (e.g.) computing or superconductivity. He would have no objection if Member States' subscriptions were paid through the EU provided the budget remained unchanged and bureaucracy was not increased, but thought there would be little support among the Council; some were not Members of the EU and CERN had proved itself to be efficient.

The USA did not contribute directly to CERN, and negotiations for it to pay toward the development of the LHC were complicated by the number of US bodies involved; negotiations could be overturned by congressional committees. US particle physicists had been told that money for CERN would have to come from their existing budgets. Some 25% of US particle physicists were planning to work at the LHC. The US would provide just under 20% of LHC users but would contribute less than 5% of its cost. The choice was between expelling US physicists or accepting the funds available. Four hundred European physicists carried out particle or high energy nuclear physics experiments at US accelerators, and European scientists were using US facilities free of charge in many other fields of science (an open door policy had developed after the war). The US had said in negotiations recently that if they were not allowed to participate they would "pull the plug" on access to their facilities for European scientists - CERN was therefore left with very little choice. Although the level of US involvement was disappointing it was the first time that the US had put funds into constructing an international project located outside the US. The Japanese had given $50m toward the LHC and were expected to contribute twice as much again; this was generous, since they had only 38 scientists at CERN. Israel had been contributing for some time and there were, or were soon to be, agreements with Canada, India and Russia. CERN was developing into a global collaboration.

The founding Treaty made no provision for host states to pay a surcharge to reflect the economic benefit they received from CERN; however France and Switzerland had agreed to make *ex gratia* payments (amounting to some 200 million Swiss francs) in addition to their individual contributions - the Swiss were to build a transfer tunnel; France was to provide specialised engineering design work; both would index their contributions by 2% from 1998 onwards, as opposed to the 1% increase in budget contributions by the other countries.

The Director General said that some countries (Italy and Spain among others) paid their subscriptions through the Foreign Office; this removed the payments from controversy but he wondered whether the budget could be vulnerable if it was handled by the FCO.

There was a division over whether non-European countries should be admitted as Members of CERN; the UK was happy to see a widening membership, but other countries thought of CERN as solely a European venture. In any case, no non-European country had expressed an interest in membership (apart from Israel). The Director General felt that global collaborations should be based on existing installations; building the facilities for mega-science on a green field site would be prohibitively expensive.

The work done at CERN pushed back the frontiers of human knowledge; it dealt with pre-occupations as old as civilisation. Although new discoveries could not be guaranteed, it was certain they would not be made if the search was abandoned. It also attracted young people into science.

Although particle physics was twice as expensive per head as other sciences, the budget of CERN was only that of a large European university; it was an efficient way of taking part in an expensive activity. It was notable that CERN's budget had remained stable in real terms while Member States' GNP had increased. In addition, while "spin off" was not the point of the research, spin-offs such as the World Wide Web and new medical imaging techniques had occurred.

Research conducted in the 1970s had indicated that high technology companies such as Oxford Instruments gained extra turnover, over and above the contract value, from contracts placed by CERN. However, CERN could not be justified on these grounds alone.

Most participating countries had industrial liaison officers (ILO) in CERN (the UK had yet to replace the ILO who had recently retired at Rutherford Appleton Laboratory). A new procedure to allow companies from countries which received few contracts in proportion to their subscriptions to re-submit a tender which was within 20% of the lowest bid was designed to encourage wider and fairer industrial participation without incurring the rigidities and inefficiencies of "juste retour". Although host countries did benefit in the operating phase of machines, contracts for major construction projects, such as the LHC, were placed throughout Europe and the weakness of sterling meant that UK industry was in a particularly strong position to tender for contracts.

For the future, Professor Llewellyn Smith pointed out the LHC would not be completed until 2005. Looking much further ahead, beyond completion of the LHC experiments, was difficult, but if conventional particle physics were to end, the scientists involved would, if they were worth their salt, be able to move on to other fields.

Professor Llewellyn Smith shared PPARC's anxiety that the UK expenditure on particle physics was too low to ensure that it gained the full value from the CERN subscription; however, he felt that communication between PPARC and CERN could be improved. He had been surprised by PPARC Council's decision to seek to reduce the CERN subscription; there was provision in the Treaty for such a reduction under "special circumstances" but this had been intended to deal with cases of low per capita GNP (Greece had benefited from reductions and Germany had been granted a reduction following reunification with the impoverished East). The UK's GNP had in fact increased, and it was highly unlikely that the CERN Council would agree to such a request. He had not discussed the matter with PPARC.

It was true that if there were no successor to the LHC, CERN's budget would fall in about 2006; however, it was impossible to commit the next generation to saying, in effect, that they would never ask for another major machine. If they did, the case would have to be made when the time came.

Analysis of Some Issues in Particle Physics Prepared After the Visit to CERN

CERN's studies for a 1-on-1 TeV 30 km long CERN Linear Collider (CLIC) mentioned in the CERN publication *The Next Step*, were undertaken in studies contributing to the next stage after LEP, the outcome of which was the decision to build the LHC. The CLIC studies are only a small part of the CERN budget, they are being run down, and will terminate shortly. CERN would only consider a linear collider (based on CLIC or one of the other technologies being considered elsewhere) as a long-term successor to LHC if i) no comparable project is in prospect when the LHC comes into operation (which seems most unlikely), and ii) there is a really powerful scientific case.

Professor Llewellyn Smith shares the view of Professor George Kalmus at Rutherford that LHC could represent the last step in the building of higher energy circular particle accelerators, because of the increase of synchrotron radiation losses (the limit has been reached for circular electron machines; proton machines with energies somewhat beyond the LHC could be envisaged, but the physics potential only grows like the square root of the energy). A linear electron-positron accelerator may be built, and competing studies for a world machine with an energy up to (and eventually conceivably beyond) 1-on-1 TeV are underway in the US, Germany and Japan. Such a machine would be complementary to the LHC (cleaner discovery potential than the LHC for some phenomena, but in a more limited domain). While claims are made by respective nationals, no government support has been promised in any country.

There would be little scientific reason for building what could not be a significantly higher energy machine after these, if the Standard Model of particle physics continues to be confirmed. The construction of large linear colliders is a tremendous technical challenge, and physical (plus fiscal) limits make a machine that could extend the discovery potential well beyond that of the LHC a very distant prospect indeed. There are no other practical means in sight for obtaining higher energies from a laser beat wave or any other source.

It is therefore true that after the present capital construction period for LHC, and the subsequent experimental period exploiting it, there is not at present in prospect a justification for a large continuing high energy research programme after the LHC at CERN. However, crystal gazing on such long-time scales (over quarter of a century) is very difficult in science and technology, and has frequently been wrong in the past. Nevertheless, there is in prospect a reduction in the claims of particle physics on the science budget in the UK, starting with a drop in the CERN budget when LHC moves from the construction to the operational phase. But if the potential of the LHC is to be exploited, larger drops cannot be foreseen for the next twenty-five years. This is too long a period yet to affect seriously the career prospects of students now embarking on a research career in particle physics.

Professor Llewellyn Smith felt that the time to start cutting the particle physics budget would be when it ceased to attract such able students. While it may be the case that some students are not well informed on fundamental research issues in other sciences, he hoped that many particle physicists were interested and saw a wiser perspective.

Answers by Professor C H Llewellyn Smith to Specific Questions put by the Committee

Q1. At a time when it is difficult for graduates to get jobs, where there is an attractive opportunity for a specific class of student, is not that opportunity likely to attract a significant proportion of that class? So is not particle physics because of its fundamental difficulty likely to attract good physics graduates?

A. The outstanding students taken on by PPARC (in astronomy and particle physics) have the capabilities to get other jobs if they wished, even in the present market, and are not motivated by the need for a job a very demanding and ill-paid job incidentally (although possibly some of the marginal/less motivated candidates may be encouraged by such considerations).

Q2. Do not particle physicists owe it to their students who are attracted by working on "the fundamentals" to encourage them at least to read what has been written by other kinds of scientists and philosophers of science about what "fundamental" means, and to look at how it works out in practice?

A. All scientists have an obligation to make sure that their students receive a broad education (in common with almost all scientists, however, I personally do not think that study of the philosophy of science although an interesting discipline in its own right is particularly important or useful for scientists). In this respect, particle physicists are no different from other scientists and I know of nothing to suggest that they have been worse (or better) than average in fulfilling this obligation.

Q3. What expenditure has been incurred on CLIC (CERN Linear Collider) studies? When will they be terminated; and why have they continued so far?

A. Since the late 1980s, about 1/2% of CERN's resources have gone into CLIC. CERN's work on CLIC is part of an ongoing world-wide effort to develop linear colliders. CLIC will certainly not be built at CERN in the foreseeable future, but it is (just) conceivable that CERN's unique approach could be adopted elsewhere, and techniques developed in the course of the CLIC study will undoubtedly have other applications (e.g. precision alignment techniques developed for CLIC will be used in the LHC). There is a case for continuing the CLIC work, not least to allow CERN direct access as an active participant to technologies being developed in other linear collider R&D work. Nevertheless, following the approval of the LHC, we cut the budget by one-third to the minimal viable level needed to capitalise on the effort already made, while bringing it to a rapid end in three years time.

Q4. Is it correct that, even if the LHC is built in two stages, the full array of experiments will be put in place at the first running of the machine, and the cost of joining experiments will not be reduced? What scope is there for phasing in experiments to reduce annual costs?

A. CERN plans to have four major detectors in place when the machine comes into operation (two general-purpose detectors, with complementary capabilities, and two somewhat smaller specialised detectors). In principle, one or more of these detectors could be built to come into operation later, but this narrowing of the programme would seriously damage the intellectual vitality of European particle physics. The large detectors can and to some extent will be "staged" (i.e. parts can be phased in later), but only to the extent of postponing up to 10% of the investment as the basic infrastructure and key elements of the whole detector (including the huge magnets whose cost represents 25% of the total) must be in place from the beginning.

ANNEX III

VISIT TO ESA ON TUESDAY 23 APRIL 1996

Members present:

The Chairman	Mrs Anne Campbell
Mr Spencer Batiste	Dr Lynne Jones
Dr Jeremy Bray	Sir Trevor Skeet
Mr Ian Bruce	Mr Patrick Thompson

[Copies of the transparencies used in the presentation have been deposited in the Library]

Points Made In Discussion

Representation at Council

The level of representation depended on the country involved; France and Germany were represented through their national space agencies. The Swedish delegation was headed by the President of the Royal Academy of Sciences.

PPARC communicated with M Luton through the BNSC; Dr Bonnet communicated with PPARC routinely; at Council the UK was represented by PPARC or BNSC according to whether the scientific or the optional programme was being debated. PPARC was usually represented by Dr Murdin or Dr Corbett.

Budget Contributions

M Luton believed that subscriptions were usually paid by Ministries.

ESA developed new technologies and span them off to industry. About a third of Arianespace was owned by CNES; the rest by companies from ESA member states in proportion to their contributions. There was no direct connection between the ESA budget and the income of Arianespace, which paid for the use of the Kourou base launch by launch in 1996 these payments would cover about half the cost of the Kourou base. However, at the 1995 Ministerial Council in Toulouse it had been decided that Arianespace should provide about £500m towards the cost for the transition from Ariane 4 to Ariane 5 (about half the cost).

Reasons for Contributing to ESA

In answer to a question from Mr Thompson, M Luton said other countries invested more in ESA than the minimum required because they each had a vision of how they wished to develop their space activities, for example, France had a keen interest in launchers, Germany in manned space. The optional programme had been developed since not all member states wished to subscribe to these activities. ESA was a civil organisation and the funding for the mandatory programme came from countries' civil budgets; however it was clear that there could be synergy between the ESA programmes a country used and its defence activities.

Relationships with the European Union

ESA had tried to get funds from the EU for research projects with no success. It wished to have the capacity for greater exports, which depended on EU business regulations. However, the EU's impact on ESA could only be limited. The EU research budget was about 3 bn (ECU) over 5 years while ESA spent 2.7bn Ecu. While M Luton had no objection in principle to the EU paying member states' subscriptions he pointed out the EU (and, through it, its member states) wished to push the research it supported nearer market.

In answer to a question from Dr Bray, M Luton said it was not clear that the Commission's tendency to appeal to EU citizens over the heads of elected government would be a problem; discussions in ESA Council were partial; each country considered decisions in the light of its own interest, perhaps without considering the long term business or defence issues; the EU might supply more vision. The issue was how much each country wished to preserve its autonomy. Moreover, even within individual countries, departments concentrated on the programmes for which they were financially responsible rather than sharing an overall vision. Companies spun off from ESA, such as EUTELSAT, paid dividends to shareholders rather than funding research.

Juste Retour

"Juste Retour" (a term which M Luton disliked) was a condition for the existence of ESA; each country wished to know what it would receive before agreeing to a programme; bargaining was always involved in international collaborations. There was a working party to examine how to reform the Agency's industrial policy and at the end of the year there would be a ministerial meeting to discuss the new proposal. Dr Bonnet said there had been a study on the commissioning of Cluster, using small companies, which had surprised him by indicating that the savings from relaxing the rules were only 10 per cent; he had expected they would be greater. M Luton said that there would be a reduction in ESA costs but he was not convinced that these efforts would be rewarded by greater support from the UK. Although efficiency was important, ESA's budget could not be reduced indefinitely and it would be impossible to make enough savings to produce the resources needed; the science programme had made efficiency savings some time ago.

M Luton then left the meeting.

Lunar Programme

Dr Bonnet said that the space station had been criticised by the scientific community as a programme promoted mainly for political ends. Following President Bush's announcement of the return to the moon, ESA had set up a working group of scientists to see if there was there was anything of scientific interest in such a programme; it had concluded that there was. Some countries had also taken the view that there would be real scientific, technical and political advantages from the proposal and had asked ESA to prepare for it. ESA had defined the steps for deciding on its participation - the first was studies to ensure it was of interest; these had started but there was no substantial budget. Although he thought there was a great deal of uncertainty about the usefulness of a moon station, it was worth examination. The Japanese space programme had taken up the ESA moon programme.

Scientific Committees

A scientific advisory Committee was appointed *ad hominem*. The Science Programme Committee, which contained representation of research organisations and scientific advisors, operated under the same rules as the Council. It was chaired by Professor Southwood of Imperial College.

Mandatory Programme

The mandatory budget provided launches and services but **not** the payload since if ESA paid for instruments countries might expect scientific return to be pro rata as they did industrial return.

Although ESA's expenditure on space science was five times less than that of the US it remained a world leader; the Infra Red Space Observatory (on which Professor Clegg from Queen Mary and Westfield College had the responsibility of a major instrument) and the recently launched SOHO mission were making very important discoveries.

Debris

ESA was taking action on space debris, but this could only be properly tackled at international levels. The space science programme did not cause problems since its probes either went into deep space or because of their relatively small size would not present any harm and be burnt while re-entering the Earth's atmosphere.

UK Scientific Standing

The UK still had a strong scientific presence in the subject, although the space science budget had decreased steadily, and more rapidly than in other countries. The UK delegation had been extremely supportive of the space science programme but this appeared to have changed after 1993. The creation of PPARC had put "big science" into a ghetto in which ground based astronomy, space science and particle physics competed with one another. Dr Bonnet had found it easier to deal with SERC than with PPARC. Communications between PPARC and ESA had not been so good in the past. In addition he had been surprised that the Chief Executive had not attended Council or preparations for it.

UK participation in INTEGRAL would have cost £12 million. UK scientists would be involved as advisors in the programme and as observers but the UK decision not to participate had increased budgetary pressure on other parties, and if the UK failed to participate in other missions its scientific standing would decline rapidly. "Juste Retour" did not apply to scientific **instruments** and although it had determined the award of the prime contractorship for XMM to a German Company the UK's failure to participate in INTEGRAL had not affected this. However, the UK's low expenditure on the optional programme did not help the scientific community.

Efficiency on the Science Programme and Reductions in Budget

Dr Bonnet thought it was difficult to quantify the effects of a cut in the science programme on Europe's competitiveness with the UK but the science programme had given innovative industry the opportunity to develop and demonstrate new techniques; this would be reduced unless military programmes filled the gap.

There had been repeated studies of the science programme; claims it was inefficient were "just UK slogans." The budget was under severe pressure. The Toulouse Council had given no compensation for inflation up to 3% but 87.5% of the budget was spent in industry, which would adjust for inflation.

Even if attempts to cut the cost of future missions were successful there would have to be some reduction in activity since no reductions could be made in current programmes.

ANNEX IV

LETTER TO THE CLERK OF THE COMMITTEE FROM PROFESSOR KEN POUNDS CBE, FRS, CHIEF EXECUTIVE OF PPARC

19 June 1996

Your letter of 6 June raised several questions regarding the consequences of the recent loss of the ESA Cluster mission. I attach a copy of a note I circulated earlier this week to PPARC Council members, which I believe addresses most of your points.

On the separate question of insurance, it has never been the policy to insure science projects within ESA, a policy that - until two weeks ago - was justified by 14 consecutive successes since 1968! With hindsight, for the Science Directorate to accept the free launch offer on the first test flight to Ariane 5 was understandable, but also unwise. (I can speak with some personal experience as I successfully argued against the launch of EXOSAT in 1983 on what would have been one of the very first Ariane flights; one of the first three failed).

Given the extra uncertainty of the Cluster launch being on an untested rocket, I would guess the insurance premium for Cluster would have been *at least* 25%, or £60 million.

LETTER TO ALL COUNCIL MEMBERS FROM PROFESSOR POUNDS

17 June 1996

Dear Colleague

It is now two weeks since the Ariane 5 launch failure and I thought I should bring you up to date with developments.

First, on housekeeping matters, we have ascertained that the number of PPARC-funded research staff directly affected totals 45, being a mix of operational and science exploitation posts. The 'domestic' spend on Cluster is of order £17.5 million, of which some £2.5 million is not yet firmly committed. To complete the picture, the UK pro-rata share of the Cluster mission costs, through ESA, is of order £35 million (but with ~£30 million returned to the UK in contracts), while some 20 permanent staff and rather more research students are also directly affected by the Cluster loss.

Within the science community and in ESA efforts are now being concentrated on recovering as much as possible of the lost science. The attached note, prepared for me by Stan Cowley shortly after the launch failure, summarises the science situation. Today and tomorrow, a meeting of PI's is taking place in ESA to discuss possible options.

These will then be reviewed at an emergency meeting of the Science Programme Committee on Friday, which I plan to attend. Then, next Monday, we have arranged a Town Meeting in London for the UK groups involved.

Two key factors in choosing the best form of 'rescue mission' are cost and timescale. Both ESA and individual members states will have difficulty finding substantial funds for a Cluster repeat, without seriously impacting on subsequent missions. Equally important, a major part of Cluster's science potential arises as a result of the links with related missions such as SOHO, Polar, Geotail, etc and the networks of ground radars now in place.

For the latter reason, the option of a single re-furbished Cluster spacecraft plus several microsatellites, is the most attractive scientifically. If this could be put together within, say, two years it would also avoid the most valuable asset of all being dissipated, namely the science teams and many research programmes which depend on Cluster data.

As to the affordability of a rescue mission to PPARC, we will have to look at any proposals very carefully. The order of costs for a spin stabilised 30-50kg spacecraft are probably £500k, which would need to be judged against the science return. It could be relevant that BNSC are presently looking at a national programme of 'small satellites', in which there is interest from the DRA and others.

I will keep you informed.

The Post-Cluster Scene - Ways Forward

The Intended Cluster Programme

A successful launch of the Cluster mission would have opened new avenues of research in a number of areas:

(1) Aspects unique to the four-spacecraft configuration - the orientation, motion and thickness of key magnetospheric boundary structures; determination of the electric current density in space; determination of the three-dimensional structure of space plasma regimes; investigation of wave structures in space; etc.

(2) Primary exploration of the dayside polar regions of the Earth's magnetosphere and dayside cusp - potentially a major site of solar wind plasma entry into the Earth's magnetosphere and atmosphere (previously only measured at very low resolution by the ESRO HEOS II spacecraft in 1972).

(3) Examination, in coordination with other spacecraft, of the evolution of the substorm-disturbed region of the nightside of the Earth (origins of aurorae and magnetic storms).

(4) Coordination with new ground-based instruments (the Cutlass HF radar, EISCAT/ESR incoherent scatter radars, IMAGE/SAMNET magnetometer networks), to examine magnetosphere-ionosphere coupling processes, particularly the ionospheric signatures of solar wind coupling processes at the magnetopause [see item (2) above], and impulsive phenomena in the tail [item (3) above].

What can be salvaged in the medium term?

Obviously a re-run of Cluster as originally envisaged would be required to address all of these areas. This seems unlikely, considering cost, time scale (-4-5 years) and other human factors. A more realistic possibility would be to use the Cluster flight-spare spacecraft and experiments, augmented by three small-sats provided quickly and cheaply eg by member nations. This could probably be done in a -2-3 year programme, and would recover some (but not all) of the original Cluster science. If only a solo "Cluster" spacecraft were to be orbited in the intended orbit, then item (1) above would be lost completely, but items (2)-(4) could still go ahead, and a good case could be made on these bases. If no mitigating action at all is taken, then items (1) and (2) would be lost, but items (3) and (4) could go ahead using existing or new approved space missions.

What can be done in the short term?

In the shorter term, there is still much first-rate work which can be done by redirecting the activities of scientific and operations staff to other areas, as follows:

(1) Redirect emphasis and accelerate work on past and present space missions - the UK community is involved in a number of existing space missions, such as Ulysses (ESA/NASA solar polar mission). Polar (NASA polar Earth-orbiting mission), other ISTP spacecraft such as Geotail and Wind (NASA/ISAS) and CRRES (NASA/DoD radiation belts mission), work on which could be accelerated.

(2) Increase preparedness for fuller participation in new approved national (non-UK) missions (which may have been considered more as Cluster "value-added" activities before 4 June). These include:

* Equator-S (German national magnetospheric mission due for launch in first quarter of 1997, which would allow items (3) and (4) above to be addressed);

* Ørsted (Danish national mission, due also for launch in the first quarter of 1997, to make precise measurements of the Earth's field from low-altitude orbit - would coordinate with ground-based experiments on magnetosphere-ionosphere coupling;

* FAST (NASA mission, due for launch in last quarter of this year, to make high time resolution measurements of auroral plasma processes from low altitudes - would coordinate with ground-based experiments);

* EISAT-1 (Irish national auroral zone mission from low Earth orbit, planned for launch at end of 1997 - would again coordinate with ground-based missions).

(3) Explore new avenues of experimental research via future missions, such as the Impact/Ibiza proposal (a German/French/Swedish/UK proposal for a two-satellite auroral zone mission, which might be launched in -2001) and a national small-sat programme (eg exploiting launch possibilities offered by the DRA STRV programme).

(4) Redeploy staff to mission-planning and development on approved new posts opening in future programmes such as Cassini and Rosetta.

How much is the ground-based programme affected?

The ground-based programme is relatively insulated from the above problems. First, a substantial amount of new work can be done using the ground-based facilities on their own. The unique location and capabilities of the ESR, the viewing area of Cutlass over the ESR, EISCAT, and the Heating facility, and the expanded spatial coverage of the SuperDARN system, guarantee a first-rate future programme. Second, new opportunities to undertake novel ground-space experiments of various kinds will open up in the near and medium term; even if no replacement for Cluster is flown. These include joint work with Equator-S (coordinated observations of magnetopause coupling and tail dynamics, similar to that planned for Cluster), and low-altitude spacecraft such as FAST, Ørsted, and EISAT-1 mentioned above (magnetosphere-ionosphere coupling and auroral physics).

ANNEX V

LETTER TO SIR GILES SHAW FROM THE THEN CHANCELLOR OF THE DUCHY OF LANCASTER, RT HON DAVID HUNT MP

29 December 1994

Thank you for your letter of 5 December concerning the Large Hadron Collider (LHC) project at CERN.

As you will no doubt be aware, formal approval for the LHC project to go ahead was unanimously granted by CERN member states at the CERN Council meeting on 16 December. This concluded many months of intense and often difficult negotiations between ourselves, CERN Management and other member states.

It is not entirely true to say discussions over an appropriate host states' contribution was preventing formal approval of the LHC. This was one part of a total package, including economies at CERN, on which we and German colleagues were insisting in order to ensure that the LHC went ahead on a realistic, fair and sustainable basis. Agreement on this package was not finally achieved until shortly before the CERN Council meeting last week. I believe that the planning and financial framework now agreed will ensure the LHC is carried through to completion. This success is largely attributable to the efforts of the UK and German delegations and indicates our decision to take a tough stance.

The potential scientific and financial participation of non-member states such as the United States and Japan was a key element of our strategy. The agreed planning framework makes possible completion of the LHC within the known resources of CERN over the period. It was CERN's view that our best chance of bringing in non-member states was to demonstrate that the project could go ahead without them, which we have achieved. Non-member states can now see that the only way to be involved at the leading edge of particle physics research is to join the LHC project. Their contributions will make it possible to advance the timetable for construction, but the success of the project will not depend on them. Like your Committee, I am very keen that CERN now takes the opportunity to make itself the world's first truly global collaboration of its kind. We will be giving CERN Management every assistance in securing this objective.

The agreement on the LHC is an excellent outcome for international and domestic UK science. It will deliver the world leading science we expect from the LHC over a reasonable timescale. Furthermore, compared to the basis on which CERN originally sought to proceed, the UK Science Budget can look forward to savings of some £70 million over the construction period of the project, about £5 million a year. That is money available for UK science, including our domestic particle physics programme to exploit the LHC.

Lest you have not already seen them, I enclose press releases issued by my Department and the Particle Physics and Astronomy Research Council.[158]

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[158] Not printed.

LETTER TO DR PETER WILLIAMS CBE, CHAIRMAN OF PPARC, FROM IAN TAYLOR MBE MP, MINISTER FOR SCIENCE AND TECHNOLOGY

4 July 1996

I have been reflecting on the funding difficulties caused by the United Kingdom's membership of CERN since our correspondence following your appearance before the House of Commons Select Committee on Science and Technology in May. You will appreciate that I have to consider this problem not just in the context of PPARC, but in that of the Science Budget as a whole. We are currently having to set aside an extra £18 million per year from the Science Budget because of the fluctuations in PPARC's international subscriptions. The consequence of this is less money for other exciting areas of Science, such as EQUAL and the human genome project, equipment and infrastructure and so on.

Let me recall some of the achievements made during the negotiations that led up to the approval of the Large Hadron Collider (LHC) project in December 1994. Savings of 800 million Swiss Francs over the lifetime of the project were agreed which, together with the additional contributions from the host states, will mean a reduction of 1 billion Swiss Francs in the cost of the project to the other CERN member states. Our share of this will be in line with our share of the CERN budget, approximately 14%. CERN Council agreed to the LHC on the assumption of no increase in member states' contributions before 1998, and increases below the rate of inflation thereafter. We also agreed to significant changes in the voting arrangements applicable to important budgetary decisions. Last, but certainly not least, was the agreement to a review of the LHC project before the end of 1997 which, as I am sure you know, CERN are now preparing. You will remember that at the outset of the negotiations, there was less than full support for the firm, but ultimately successful, line that we eventually took.

One important lesson to be learnt from the negotiations over the LHC is how much can be achieved by working with other member states. The United Kingdom would never have achieved what it did without working so closely with our German colleagues. We will only achieve our objectives in 1997 through this partnership. Of course, we should also try to build support with other member states, but the new voting arrangements mean that the budget can be blocked by the United Kingdom and Germany voting together. The other point that we must not lose sight of in 1997 is the size of the savings that can be achieved by negotiating seriously.

I am writing to you now to seek your agreement to a tough approach in the 1997 review. We need to ensure that the review takes a rigorous look at the cost structure of both the LHC project and the CERN organisation itself. I want to be convinced that CERN is adopting the most modern project management techniques and bearing down on its costs. Our partners on CERN Council must be clear that the United Kingdom is fully committed to the success of the LHC project, but not at any price. I believe that it is only by being firm that we can press CERN seriously to look at its costs, and ultimately bring the CERN budget and the cost of our subscription under control, thus helping to relieve the pressure on PPARC's domestic programme.

I know from my officials that the Select Committee have taken a strong interest in CERN during their enquiry into PPARC and am, therefore, copying this letter to Sir Giles Shaw for information.

PROCEEDINGS OF THE COMMITTEE RELATING TO THE REPORT

WEDNESDAY 10 JULY 1996

Members present:

Sir Giles Shaw, in the Chair

Mr Spencer Batiste	Mr Andrew Miller
Dr Jeremy Bray	Sir Trevor Skeet
Mr Ian Bruce	Mr Patrick Thompson
Mrs Anne Campbell	Sir Gerard Vaughan
Dr Lynne Jones	

The Committee deliberated.

Draft Report (The Particle Physics and Astronomy Research Council), proposed by the Chairman, brought up and read.

Ordered, That the draft Report be read a second time, paragraph by paragraph.

Paragraphs 1 to 96 read and agreed to.

Paragraph 97 postponed.

Motion made, and Question proposed, to leave out paragraphs 98 to 109 and insert the following paragraphs:

> "98. In our view the solution has to be sought in a reappraisal and re-deployment of the international efforts in research in particle physics. The cancellation by the US Congress of the SSC signals a re-appraisal by scientists and by governments of the distribution of resources within different fields of basic research in the world generally. We think it would be unfortunate if this is not recognised and accommodated in time to avoid the outright cancellation of the LHC in the manner of the SSC. We believe there is real promise in the LHC and that the programme as at present envisaged should be carried through. But it must be carried through in a way which does not offend against the wider interests of science and its role in the world community.
>
> 99. We consider first some specific proposals that have been put to us on UK participation in CERN. First it has been suggested that responsibility for major treaty based international subscriptions should be removed from the Science Budget. In the present climate on public expenditure it is inconceivable that this would happen without matching reductions in the Science Budget, making it merely a book-keeping exercise making no useful contribution to the problem.
>
> 100. Second, **it has been suggested that the Treasury should bear the cost of any fluctuations in international subscriptions arising from future fluctuations in exchange rates or relative net national incomes. We so recommend.** For the next few years such fluctuations could be downwards from the present level, but they divert attention from the underlying problem of the overall size, timing and trends of expenditure on particle physics research in relation to the overall Science Budget where the real problem lies.

101. We consider that there is a good case for a general increase in the Science Budget. Although both the Science Budget and total funding of the science base has increased in real terms over the last ten years, that spending has not kept pace with the growth in GDP. Since 1986/87 funding of the Science Base has fallen as a percentage of GDP from 0.34% to 0.30% in 1996/97. If the Science Base had grown in line with GDP it would be some £279 million higher than its current figure. In addition the Science Base has become an increasingly important part of the national research capacity, since total government expenditure on civil R&D has fallen even more quickly, from 0.61% of GDP in 1986 to 0.43% in 1994; a drop of 30%.[159] As a result the United Kingdom would now appear to spend less than all the other G7 countries on civil R&D as a percentage of GDP. In 1992 the last year for which full figures are available only Japan and the USA, countries with traditional low government expenditure on civil R&D, spent less proportionately than the United Kingdom. By 1994, it would appear that the United Kingdom had fallen behind both these countries.[160]

102. Although Research Council funding has not been as badly affected as university research funding, it has still fallen slightly in relation to the growth in GDP (after excluding the dual support transfer). Even though it is clearly Government policy to reduce the part civil departments play in commissioning R&D,[161] there will always be a need for research to underpin Government policies. We believe that as departmental research establishments are reduced in number, Government departments are likely to become even more dependent on Research Councils for scientific research and advice. We believe that Science Base funding should be increased, and the Research Councils should share in this. However, we do not consider that the proportion of the Science Budget devoted to Particle Physics should rise or that PPARC would have an automatic claim to any increase in the Science vote.

103. We noted above that PPARC has put in a bid for an additional £65.5 million for the development of the LHC and its experiments, spread over the next eight years, with the anticipation that the CERN budget will fall by up to 20% at the end of the period of construction of the LHC. At an early stage in our inquiry we did ask a number of particle physicists if they thought such an approach offered a possible course of action. While older particle physicists tended to say that the LHC represented the end of the line for particle accelerators, younger ones tended to emphasise that there were other ways of achieving higher energies. We believe that the question of the level of resources for particle physics has to be resolved now. In any case in the present climate on public expenditure, it is quite unrealistic to expect the Treasury to make specific provision for additions to the Science Budget totalling £65.5 million over 8 years for particle physics at CERN. The money would have to come out of other allocations, perhaps another £3 million a year from the domestic particle physics programme, £3 million from astronomy, and £2 million from the rest of the Science Budget. This would not be acceptable.

104. The particle physics community has to make a Solomon's judgement. Naturally each physicist, each team of physicists, and each national community of physicists would prefer to make future discoveries themselves rather than see them made by others. But are they sufficiently devoted to physics to prefer to see the discoveries made by others or shared with others rather than to see them not made at all? CERN has demonstrated decisively that physicists can pool their efforts, share the experimental results, and compete in their interpretation. What is required now is to take that experience a step further.

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[159] Cm 3257-II, Table 7.8, GDP deflator supplied by Office of National Statistics; GDP forecast for 1996/97 taken from HM Treasury *Financial Statement and Budget Report 1996-97* HC(1995-96)30.

[160] *Ibid*, Table 7.8.

[161] Expenditure has fallen by 42% in real terms over the last ten years.

105. Given present physical assets, plans and experience in the United States, Japan and Russia and other non-CERN members as well as in CERN and its member countries, what is the best next step in particle physics? Particle physicists in CERN have carried that question as far as they can, and they have secured the promise of some non-member participation in the LHC. Science ministers responsible for a wider distribution of resources have to take the next step.

106. It is clear that Germany, the largest contributor to CERN, shares UK concerns about the costs of CERN. The Minister for Science and Technology has said

> "The UK would never have achieved what it did [in reducing the costs of the LHC] without working so closely with our German colleagues. Of course, we should also try to build support with other member states [of CERN], but the new voting arrangements mean that the budget can be blocked by the United Kingdom and Germany voting together."[162]

107. **Starting with an inner circle of science ministers in the G7, science ministers should discuss what level of resources they are prepared to commit to future research in particle physics. There are constraints in all countries. In the US, Congress cancelled the SSC outright. In the UK, the constraints are first, that an efficient balance must be restored between the domestic particle physics programme and participation in CERN. And second that balance must be restored within the present total rate of UK expenditure on the particle physics programme. There are different constraints in other countries, but they exist in all.**

108. **For CERN the most efficient course would be to construct and conduct the experiments on the LHC on the present timetable. That may still be possible with increased participation in CERN or the reconstruction of CERN on a global rather than a European basis. We hope that it is. If it is not, the LHC timetable may have to be re-phased more drastically than has yet been considered. That could well change the whole nature of the LHC programme. The Minister for Science and Technology has said, "The UK is fully committed to the success of the LHC project, but not at any price."[163] We share that view.**

109. We believe that the UK would not be in a minority on the CERN Council in arguing these propositions after consultation and study by science ministers of the need for a re-distribution of resources between different fields of basic and applied science. **We do not believe there is a fixed ratio of basic to applied research that is appropriate irrespective of the composition of the basic and applied portfolios, and wider circumstances.** Priorities appropriate for one generation are not necessarily appropriate for its successors.

110. **When science ministers have considered further the future funding of particle physics research, and the practical alternatives are clearer, the successor of this Committee in the next parliament may wish to consider the matter further, perhaps meeting informally with members of responsible committees in other European legislatures, the US Congress and other non-European legislatures to discuss this and other matters of international interest in research.** — (*Dr Jeremy Bray.*)

Motion made, and Question put, That the paragraphs be read a second time.

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[162] Letter from Mr Ian Taylor to Mr Peter Williams, 4 July 1996.

[163] *Ibid.*

The Committee divided.

Ayes, 3	Noes, 6
Mr Spencer Batiste	Mrs Anne Campbell
Dr Jeremy Bray	Dr Lynne Jones
Mr Ian Bruce	Mr Andrew Miller
	Sir Trevor Skeet
	Mr Patrick Thompson
	Sir Gerard Vaughan

Postponed paragraph 97 read and agreed to.

Paragraph 98 read and agreed to,

A paragraph — (*Mr Patrick Thompson*) — brought up, and read, as follows:

> "In our view, **the most satisfactory solution would be to remove responsibility for major treaty based international subscriptions from the Science Budget. We so recommend.** There would need to be some mechanism whereby the scientific community could be consulted, but in spite of the Government's claims, membership of major international collaborations is clearly a matter of foreign policy as well as of scientific endeavour. There would be some compensating reduction in the science budget, but decisions on the allocation of funds to PPARC would be made in the certainty that that funding would be directly used to support UK researchers."

Motion made and Question put, that the paragraph be read a second time:

The Committee divided.

Ayes, 4	Noes, 5
Mrs Anne Campbell	Mr Spencer Batiste
Sir Trevor Skeet	Dr Jeremy Bray
Mr Patrick Thompson	Mr Ian Bruce
Sir Gerard Vaughan	Dr Lynne Jones
	Mr Andrew Miller

Paragraphs 99 to 110 read and agreed to.

Annexes 1 to 5 read and agreed to.

Motion made, and Question put, that the Report be the Fourth Report of the Committee to the House.

The Committee divided.

Ayes, 4	Noes, 1
Mrs Anne Campbell	Dr Jeremy Bray
Dr Lynne Jones	
Mr Andrew Miller	
Sir Trevor Skeet	

Ordered, That the Chairman do make the Report to the House.

Ordered, That the provisions of Standing Order No 116 (Select committees (reports)) be applied to the Report.

Several papers were ordered to be appended to the Minutes of Evidence.

Ordered, That the Appendices to the Minutes of Evidence taken before the Committee be reported to the House. — (*The Chairman.*)

Several Memoranda were ordered to be reported to the House.

[Adjourned till Wednesday 17th July at Four o'clock.

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Parliamentary Office of Science and Technology briefing note.

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